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Issyk-Kul
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EXECUTIVE SUMMARY

The current scientific report contains of the results obtained for the period of May 1998 – July 2003. The research objects were river waters of the Issyk-Kul hollow, water and sediment, both of the coastal and deep zones, of the Issyk-Kul Lake.

Rivers are the main suppliers of suspended substances containing terrigenous particles of precipitation rocks and organic pollutants of wastewaters, into the Issyk-Kul Lake. Mineralization and composition of the coastal zone water depends on the drain volume of running rivers with low water mineralization. Chemical composition of deep zone water has small differences both on area and depth.

Sediment formation of the lake is a result of sedimentation of suspended substances such as solid drain of river basins, phytoplankton production, entrance of polluted wastewaters including physical and chemical processes proceeding in the lake. Anthropogenic loading caused by economic activity in the lake was been evaluated as the value of the anthropogenic component, as the pollution level of water resources and the sum index of sediment pollution.

III. INTRODUCTION

The Issyk-Kul Lake basin is an ecological system consisting of nourishing rivers and ground waters where all processes of substance migration and circulation, including substances of technogenic origin, are interdependent. The Issyk-Kul Lake is one of the world's largest mountainous type terminal saline lakes located in the droughty zone of the Tien-Shan at 1,609 m above sea level. Its surface area and maximum depth are equal to 6,236 km² and 668 m, respectively. There are various valuable food fish such as trout, naked osman, marinca, sig, bream and others in the lake. The lake is widely used for recreational purposes.

Human activity in the Issyk-Kul Lake basin has increased the anthropogenic load on water resources as a result of water intake from the rivers and waste of pollutants. A major reason of lake water level decline is water intake from the rivers. During the period of 1927 – 1976, the lake level fall was approximately 3-5 cm per a year. Modern decline of the lake is 7-9 cm. From 1976 to 1979, and 1985, the level decline reached 10-13 cm. A drastic decline of the level (19 cm) was observed in 1996. For the last 70 years, total decline of the level is 3.50 m. At present, the year's water deficiency of the lake is $480 \cdot 10^6 \text{ m}^3$. According to various prognoses, it should be redoubled by 2005. If these prognoses are correct, the coastal line will then move on 500-1000 m, shoals will be revealed and some natural beaches will be lost.

Due to the development of agriculture in the Issyk-Kul area, the amount of water used for irrigation increases constantly: in 1966, 9% of river drain was used for irrigation and other purposes; in 1982, the percentage was already 34%; and in 1997, it reached 37%. The increase of water consumption due to the rise of population and the absence of proper sewage and water supply systems in the coastal zone of the Issyk-Kul Lake have caused water quality deterioration. Therefore, the local population is forced to drink polluted surface waters.

Polluted river waters, reaching the coastal zone of the lake, lead to the pollution of lake water by organic substances (petroleum, detergents, phenols and residual products of fertilizers and pesticides) and by heavy metals. All these pollutants are stable in the external environment. The current economic activity in the Issyk-Kul Lake area did not take into account the ecological effects on the local environment. Therefore, this can result in a disturbance of the natural ecological balance and a sharp deterioration of water quality in the Issyk-Kul Lake.

The Issyk-Kul water is unique for its chemical composition. Qualitative and quantitative composition of chemical substances stipulate health care by the lake water. Pollution of the lake leads to the loss of this unique lake water feature.

Active accumulators of the above-mentioned pollutants (the first-being heavy metals) are sediment. Processes, which proceed in sediment, are closely connected with suspended matters in the lake water. These substances gradually settle and are accumulated in bottom sediment. The lake sediment comprises organic and inorganic substances that are from different sources. The organic material in the sediment mainly consists of phytoplankton cells and macrophyts remains. Inorganic material is the product of mountains erosion and rock precipitation of the lake basin. Various pollutants are gradually accumulated in sediment. Therefore, the study of sediment pollution allows us to acquire information with respect to lake pollution as a result of anthropogenic activity within the Issyk-Kul basin. The value of anthropogenic loading can be evaluated either by the analysis of water or the sediment.

Ecological conditions of surface reservoirs (lake or rivers) can be evaluated on the basis of information regarding pollutant concentrations received by long-term monitoring. The sources of information regarding ecological conditions of the whole lake reservoir are the studies of sediment pollution. Sediment characterizes the level of pollution, which is an integral index of human loading. For the evaluation of technogenic loading on the Issyk-Kul Lake, we first studied chemical composition, organic pollutants and heavy metal contents in sediments of 28 gulfs and the lake deep zone.

IV. EXPERIMENTAL SECTION

1. Research objects

The research objects were rivers flowing into the Issyk-Kul Lake, water and sediment of coastal and deep zones of the lake. Water sampling was carried out at 57 stations located on the water surface of the lake on 4 transects from the northern to the southern coast:

I range – Choktal village - Akterek village;

II range – Cholpon-Ata lighthouse - Koltsovka village;

III range – Grigorievka village - Tamga village;

IV range – Orto-Uryukty village - Karabulun lighthouse (Pokrovka village).

Water sampling was carried out up to a depth of 650 m. During the research period, 787 lake water samples including 694 samples from the coastal zone and 93 samples from the deep zone of the lake were taken. Sediment sampling was carried out in the coastal zone (up to 60 m) and in the open part (up to 650 m) of the lake. 259 sediment samples were taken, including 230 samples from the coastal zone and 24 samples from the littoral zone of the lake. Thirty eight components were determined in every sample.

Five regions were chosen for our detailed study. We present here a very short description of them:

1. The Rybachi Gulf, situated at the western end of the lake, is a shallow gulf with depths of up to 25 m. Water surface of the gulf is constantly mixed by wind. Therefore, these waters are enriched in suspended matter as compared to the other parts of the lake.
2. The northern coast of the lake contains numerous bays which are open in the direction of the lake. This coast is characterized by water depths of up to 40-50 m. Special attention during this study was given to the eastern bay at the coast where the Cholpon-Ata resort center is located.
3. The southern lake coast contains bays, which are in actual fact, flooded valleys of the river estuaries. These bays are relatively deep: up to 40 m.
4. Freshwater gulfs of the east coast inflowing far into the beach (up to 10 - 12 km). The depths of the Tyup Gulf and the Dzergalan Gulf reach 35 and 50 m, respectively.
5. The central open part of the lake is characterized by depths of 50 to 668 m.

2. Methods of analysis

The analysis of water samples was performed in accordance with modern analytical methods described in the appropriate State Branch Standards (SBST), as summarized in Table 1. The determination of dissolved oxygen, temperature, pH, permanganate and dichromate oxidation, heavy metals and detergents was carried out in accordance with the techniques described in (The manual, 1977, Unified methods, 1979). Bottom sediment was analyzed by using spectral methods (Spectral analysis, 1961), gas chromatographic (Gas chromatography, 1975) and atomic adsorption methods.

Table 1. State Branch Standards for used analytical methods

Item	#SBST
Selection, storage and transportation of samples	24481-80 SBST
Bicarbonates	23446.1-85 SBST
Carbonates	23446.1-85 SBST
Sulfates	4389-72 SBST
Chlorides	4245-72 SBST
Magnesium	23268.5-78 SBST
Calcium	23268.5-78 SBST
Phosphates	18309-72 SBST
Nitrites	4192-82 SBST
Nitrates	18826-73 SBST
Ammonium	4192-82 SBST
Phenols	26449.1-85 SBST
Petroleum	26449.1-85 SBST
Major ions	26449.1-85 SBST
Biogenic compounds	26449.1-85 SBST

3. Quality control of experimental results

Quality control was conducted by using Certified State Sample (CSS) with a known content of analyzed components as follows: dry CSS was dissolved in one liter of water and analyzed for the content of major ions and heavy metals. The results obtained were compared with the CSS values. It should be noted that analyses of CSS and samples were conducted simultaneously and under the same conditions. An operative control of analytical value, i.e., relative deviation between an average value of results from two parallel measurements and a certified value of a component were calculated in accordance with the following equation:

$$d_z = \frac{\bar{C} - \hat{A}}{\hat{A}} \cdot 100, \quad \% \quad (1)$$

where \bar{C} is the average value of two parallel measurements, \hat{A} is the certified content of the component and d_z is the relative deviation. The value d_z must not exceed half of the permissible relative deviations that are regulated by SBST of this analytical method for error standards at water analysis.

The maximum permissible deviation (d_{\max}) of the average result from the certified value may be calculated as follows:

$$d_{\max} = 0,0196 \cdot \frac{\hat{A}}{\sqrt{n}} \cdot x_{d_z} \quad (2)$$

where n is the number of measurements, and x_{d_z} is a permissible relative average squared deviation of the measurement result regulated with the normative document (Standards of analysis accuracy, 1987).

Quality control of the experimental results was carried out using standard sample analysis. According to this technique, distilled water with an addition of known amount of a determined component was used as a standard sample. Six repeated determinations were carried out with each standard sample. The analyses of the standards were performed either after each new preparation of fresh reagents or the plotting of new calibration diagrams, or after repairing any piece of equipment. After conducting several repeated measurements, the average systematic error ΔS_{syst} and the relative systematic error δS_{syst} were calculated in accordance with the equations taken from Doerfel (1969) and Alekseev and Korovin (1972).

Relative deviations for the results of major ions determination are within 0.339% for sulfates, 1.768% for magnesium and 2.033-3.765% for heavy metals; that is within permissible errors (Table A-1).

4. Analysis of experimental data

We systematized and analyzed the material related to hydrochemistry of the lake collected by the Hydrometeorology Management during the period of 1975 to 1982 in order to characterize the pollution condition of Issyk-Kul Lake water. In addition, the archives for 1985 – 1992 and the data received during fulfillment of the current grant in 1998 were also analyzed (Table A-2).

Comparison of the hydrochemical characteristics of the lake has shown that the characteristic pollutants of Issyk-Kul Lake water and its rivers are petroleum and heavy metals (copper and zinc). The coastal zone of the lake was polluted by petroleum with the average annual contents for the period of 1975 to 1982 from 0.00 to 0.69 mg/l. The deep part of the lake was less polluted: the average annual content changed from 0.05 to 0.20 mg/l, and annual content variation did not exceed 0.50 mg/l. The highest petroleum concentrations were found at the following sites: the Rybachi Gulf (1.4-37 MPCs), the Tyup Gulf (1.2-9.6 MPCs), and the east bay of Cholpon-Ata (1.4-15 MPCs). In the coastal zone (the Kajisay River estuary), the petroleum concentrations exceeded MPC by 1.4-6.4 times.

The content of heavy metals on the surface (0.5 m) layer of lake water was observed to have a tendency of decreasing. At the coastal zone of the Kajisay Village and at the east bay of Cholpon-Ata, the maximum contents of copper were found to be equal to 0.009 and 0.008 mg/l, respectively. As a rule, the contents of heavy metal ions in the bottom layer of lake water were lower than those in the superficial layer or are equal to them. The deep-water zone was characterized by higher concentrations of copper as compared to those in coastal waters ($C_{\text{avg}}=0.004$ mg/l, $C_{\text{max}}=0.026$ mg/l). Phenol concentrations in the surface waters of the Issyk-Kul Lake basin were found to change from 0 to 0.14 mg/l.

Other pollutants found in some samples were pesticides (0.001-0.009 mg/l). The largest concentrations of pesticides were found during the period of 1976 - 1979. Their concentrations occasionally reached 0.002 mg/l in the lake water. The average annual content of nitrites in the lake water changed from 0.002 up to 0.008 mg/l. Their highest concentrations were observed in the Rybachi Gulf (0.027 mg/l) and in the Tyup Gulf (0.018 mg/l) during spring. Concentrations of nitrates, detergents and iron did not exceed the MPC norms.

The oxygen regime of the lake was favorable throughout all studied seasons: the amounts of samples with oxygen contents lower than MPC (6 mg/l) did not exceed 2 %.

Violations of the oxygen regime were observed at the Tyup Gulf in the bottom layer of the water only during August 1998.

Analysis of archive material during the periods of 1975-1982 and 1985-1992 has shown that anthropogenic activity in the Issyk-Kul Lake basin has essentially influenced the pollutant contents in coastal waters of the lake, especially in river waters. Data for the period of 1998-2002 showed that, during this period, anthropogenic loading on water resources of the Issyk-Kul Lake basin decreased in comparison with other studied periods. It was caused by the decline of tourism, industrial crises and the decrease of livestock. On the other hand, a control for the polluted drain discharges was not conducted. Pollutant loading has not essentially affected the deep water of the lake. The main reason for this was the large volume of water mass possessing high buffer capacity and self-purification ability. However, due to constant reduction of lake water mass, the self-purification ability of the lake waters decreases, therefore, possibly causing lake pollution to increase in future.

V. RESULTS AND DISCUSSIONS

1. *Running river water*

The rivers of the Issyk-Kul Lake basin are typical high mountainous rivers with rapid streams. The rivers mainly have glacial-snow nourishment. The river network is irregularly distributed in the basin. The western part is developed very poorly. In the eastern part of the basin, the deepest rivers (Tyup, Dzergalan, Karakol, Chon-Kyzylsu, Dzety-Oguz, Aksu) are situated. Their drain is $1992.4 \cdot 10^6 \text{ m}^3$. Rivers of the southern coast are deeper ($1105.1 \cdot 10^6 \text{ m}^3$) than the northern ones ($479.7 \cdot 10^6 \text{ m}^3$).

River water is characterized by low mineralization (Table A-3). The river water of the northern coast has the lowest concentration of salts ($157.4\text{-}308.8 \text{ mg/dm}^3$) while the rivers of the western part of the lake have the highest (633.7 mg/dm^3). The average water mineralization of the rivers of the Issyk-Kul Lake basin is 258.6 mg/dm^3 . Chemical analysis of the river water shows calcium and hydrocarbonate ions prevail in the chemical water composition.

During the year, season mineralization and major ion content in water depends on the change of river water drain determined by their nourishment type. In winter and early spring, the rivers are nourished by ground waters and mineralization of river waters increases. During warm seasons, the river drain mainly consists of melted snow and ice with low salt concentrations. Formation of chemical composition of the river waters proceeds at a height more than 3000 m above sea level at conditions of low air temperature, large reserves of snow and glaciers and a prevalence of hardly leaching rocks. These peculiarities of high mountainous zones form river drains with low water mineralization of hydrocarbonate calcium composition. The main sources of lake pollution are river basins with villages and towns having undeveloped infrastructure. Concentrations of pollutants in river waters are summarized in Table A-4.

Among the nitrogen compounds, nitrates ($C \leq 0.37 \text{ mg/dm}^3$) prevailed in river water in spring (the Toruaigyr, Tyup, Barskaun Rivers). For fish-breeding purposes, norms of maximum permissible concentration (MPCs) of nitrates in water are 0.10 mg/dm^3 . Therefore, nitrate nitrogen contents in river waters exceeded the normal level of 13 (the Tamga River) to 37 times (the Toruaigyr River). The concentration of nitrite nitrogen does not exceed MPC norms in all rivers studied. This fact may be explained by the instability of nitrite nitrogen and its conversion into nitrate due to its oxidation by air oxygen. The main index of surface water pollution by household drains is the presence of ammonium nitrogen in the water. MPC of ammonium nitrogen is 0.05 mg/dm^3 . In the Toruaigyr and the Ton River water, ammonium nitrogen

concentrations were 5.4 and 4.0 higher than MPC, respectively, and in the Barskaun and Dzergalan Rivers over 3.2 times that of MPC.

Phosphorus content is not controlled in surface reservoirs that have fish-breeding importance. In river water, the concentration of phosphorus was 0.00-0.40 mg/dm³.

The main source of river water pollution is waste discharges of towns, villages and boarding houses. There are no sewage systems in the villages, therefore, most of the non-purified drains are discharged in the rivers which, therefore, cause their pollution.

Among organic pollutants, high concentrations of phenol, which exceed the MPCs 4 times over were found in the waters of the Aksu River, the Semionovka village and the Chon-Kyzylsu River. Detergents and petroleum concentrations were 0.005-0.018 mg/dm³ and 0.001-0.005 mg/dm³, respectively, and did not exceed permissible levels.

Among the heavy metals, iron, copper, zinc, lead, cadmium and tin were determined in the river water (Table A-5). Copper concentration was the highest among concentrations of other heavy metals in the river waters. Copper concentration exceeds MPC norms by 13-47 times in the Aksu River, the Teplokluhenka village, the Ton River, the Ton village, the Barskaun River estuary, the Kurmenty River and the Kurmenty village. Concentrations of other metals are minimal, and tin was below detection level.

It should be mentioned that the highest anthropogenic loading in river waters occurred in summer due to resort activity. During spring and fall, the main pollutants were nitrogen compounds (nitrates and ammonium) that arrive with melted waters from irrigated tracts of land. During the summer, the main source of pollution was non-purified waters of villages, towns and sanatoriums. Phenols, heavy metals and petroleum appear in the river water during this season. Natural hydrological regime of the region rivers was broken as a result of the economic activity. The intake of large river water volume caused the decrease of the self-purifying ability of river water, worsening of the landscape and aesthetic view, water deterioration and other negative side effects. In the zone of the river drain formation, water quality was mainly conditioned on lithological composition of rocks, which compose well fields, and conditions of drain formation. Waters of the formation zone have low mineralization. In all rivers, maximum water mineralization was observed during low floods and minimum mineralization – during high floods.

Concentrations of specific pollutants (petroleum, phenols and heavy metals with the exception of copper and zinc) did not exceed the MPCs or exceeded them at an insignificant level. The quality of river waters was much worse in the zone of drain consumption owing to the regulation of river drain volume and anthropogenic pollution than in the formation zone. Transformation of river drain quality was displayed in the increase of water mineralization due to river lengths and exceeded the MPCs for petroleum, phenols, detergents, heavy metals, nitrates and ammonium ions by 2-4 or even 10-20 times (Tables A-4, A-5).

2. Water of coastal zone of the lake

Numerous gulfs and river estuaries characterize the coastal zone of the Issyk-Kul Lake. The total number of gulfs is 28. Gulfs of the northern, eastern and southern coasts of the lake have their morphological peculiarities. Some of them are stretched and deep, with steep banks and cut deep inland. They are flooded beds of the rivers (the Tyup and Dzergalan Gulfs). The second group of the gulfs is widely open to the lake with flat banks. The gulfs of the northern coast (with the exception of the Pokrovsky Gulf situated in the south coast) belong to this group: the Chok-Tal, Dolinka, Cholpon-Ata and Grigorievka Gulfs. As a rule, gulfs of the southern coast (Akterek, Ton, Koltsovka, Tamga and Barskaun) are narrow, with lengths of 1-3 km and are river estuaries.

Water mineralization in the coastal zone of the lake changes in wide limits that can be explained by the influence of the river drain. Many rivers, especially those on northern coast (Chyrpykty, Toruaigyr, Cholpon-Ata, Sary-Oi, Oital and others), are used only for irrigation purposes and do not drain into the lake. Therefore, the gulfs of the north and west coasts have the highest mineralization (Table A-6). Mineralization of the coastal zone water is within 2,420-5,960 mg/dm³. The river drain with low mineralization decreases salt content in the gulf waters. Due to the differences between specific gravity of the river and lake waters, their mixing takes place gradually. River waters remain on the surface layer for a long period of time and sweeten the lake water. Mineralization of the lake water is within 2,572-3,886 mg/dm³ in the river estuaries of the gulfs in immediate proximity to the coast.

There is no river drain in the Rybachy and Cholpon-Ata Gulfs; therefore, their water mineralization changes insignificantly with the increase of distance from the coast. In the Dzergalan Gulf, water mineralization is 3,886.9 mg/dm³ near the Dzergalan River estuary; it rises with the increase of distance from the coast and reaches 5,642.8 mg/dm³ at a distance of 14.3 km. In the Tyup Gulf, the increase of water mineralization is also observed as one moves further from the Tyup River estuary: salt content is 2,572.9 mg/dm³ at a distance of 0.1 km and 5,561.0 mg/dm³ in 15.5 km, respectively. Water composition in the gulfs with river drains is sulfate-chloride-sodium, but it then becomes chloride-sulfate-sodium as it distances itself from the coast. Running river waters of hydrocarbonate-calcium composition influence the carbonate regime of the lake.

The coastal zone of the lake is characterized by relatively high alkaline reserve (2.49-2.65 mg-equiv/l). There is no MgCO₃ precipitation in the lake waters, meaning that they are undersaturated in relation to magnesium carbonate. However, surface waters of gulfs are oversaturated in relation to calcium carbonate and their precipitation was widely observed. When river waters oversaturated with calcium carbonate reach the coastal zone of the lake, precipitation of calcium carbonate occurs on the surface layers of the lake. This process takes place during summer when an amount of free carbonic acid dissolved in the water decreases, and accordingly, a solubility of calcium carbonate decreases. Calcium carbonate concretions are specific peculiarities of the Issyk-Kul Lake, and they are deposited as separate congestions on rocks. Lime concretions are deposited from a depth of 0.1-1.5 m to 15 m over the entire lake with the exception of places with either silt or sandy bottoms. Precipitation of calcium carbonate is important for the stabilization of chemical composition of lake water. A significant part of calcium ions and hydrocarbonates, arriving with river drain into the lake, forms deposits of calcium carbonate while the carbonate content of the lake remains constant.

Contents of biogenic elements and organic pollutants in the coastal zone water of the Issyk-Kul Lake (1998-2002) are summarized in Table A-7. The concentration of nitrite nitrogen is within 0.000-0.027 mg/dm³, nitrate nitrogen – 0.000-0.157 mg/dm³ and ammonium nitrogen - 0.000-0.085 mg/dm³. MPC values of nitrite nitrogen are 1.3 times higher in the Akterek Gulf and Rogataya bay. In the other gulfs, nitrite nitrogen concentration is within MPC values. The concentration of nitrate nitrogen is higher than MPC values by 3.1 in the Rybachy Gulf, 2.9 times in the Shiroky inlet and 2.1 times near the tourist center in the Ananievo village. Contents of ammonium nitrogen and phosphorus do not exceed MPC levels. Low concentrations of nitrogen and phosphorus nutrient elements characterize the Issyk-Kul Lake as an oligotrophic lake. Among other pollutants, phenol presence is the highest concentration in waters of the coastal zone (Table A-7). Phenol concentrations exceed the MPC level (0.001 mg/dm³) in the Grigorievka Gulf by 3 times, in the Ton and Koltsovka Gulfs - 8 times and in the Akterek Gulf - 12 times. Petroleum and detergent concentrations are 0.000-0.004 mg/dm³ and 0.001-0.016 mg/dm³, respectively, and do not exceed MPC values.

Heavy metal (iron, copper, zinc, lead, cadmium, tin and arsenic) contents in the coastal zone water of the Issyk-Kul Lake (1998-2002) are presented in Table A-8. Permissible values of

MPC for heavy metals in the lake water are as follows: iron – 0.05, copper – 0.001, zinc – 0.01, lead – 0.03, cadmium – 0.005, tin – 0.001 and arsenic – 0.01 mg/dm³. Iron content is higher than its MPC value by 1.2 times in the Tamga Gulf, 2.3 times in the Ton Gulf, 2.8 times in the Akterek Gulf, 3.1 times in the Ak-Chiya Gulf and 10.1 times in the Koltsovka Gulf. Copper content is double its permissible MPC value in the waters of the Rybachy, Dzergalan, Pokrovsky and Tamga Gulfs, 5 times higher than permissible in the region of the Ananievo Tourist Center and Kurmenty dock and 7 times higher in the Kursky Gulf. Zinc concentration exceeds MPC values by 4 times in the Rybachi Gulf, and 5 times in the Pokrovski Gulf. Concentrations of lead and cadmium do not exceed MPC values in the waters of the coastal zone. A high content of tin was found in the Issyk-Kul Lake water. Tin MPC values were found to exceed 7-14 times in the Kurmenty dock, 38 times in the Tamga Gulf and 42 times in the Akterek Gulf. Arsenic contents exceed MPC values in the water of the south coast gulfs by 1.1-1.6 times (Tamga and Koltsovka).

Contents of silicon and fluorine, which have a medicinal influence upon human health, were determined in gulf water samples. Distribution of these elements in gulf waters according to depths is summarized in Table A-9. Silicon concentration (1.9 mg/dm³) is constant in the Rybachy, Dzergalan and Pokrovsky Gulfs, 1.9-2.0 mg/dm³ – in the Cholpon-Ata Gulf, 1.8-2.2 mg/dm³ – in the Tyup Gulf and 1.8-1.9 mg/dm³ – in the Kajisay Gulf. Fluorine content is considerably less in the surface water layers than in layers situated below. Maximum fluorine concentration is 12.8-14.3 mg/dm³ in the Rybachy Gulf, 11.0-14.0 mg/dm³ – in the Cholpon-Ata, Pokrovsky and Ton Gulfs, 8.9-13.2 mg/dm³ – in the Tyup Gulf and 5.7-13.5 mg/dm³ – in the Dzergalan Gulf. In the deep zone of the lake, fluorine concentration is constant at different depths: 13.5 mg/dm³ (the Tamga Gulf) – 14.3 mg/dm³ (the Koltsovka Gulf).

Thus, the coastal zone of the lake is found to be influenced by large anthropogenic loading. This is confirmed by the presence of high concentrations of nitrate nitrogen, phenol, petroleum and heavy metals. The most polluted gulfs are the Rybachy, Dzergalan, Tyup, Akterek, Koltsovka and Kurmenty ones.

3. Deep Water of the lake

The deep central part of the lake (with depths of 100 to 668 m) is characterized by vertical and horizontal water circulation that is one of the specific peculiarities of the lake. In 1998 and 2001, the distribution of mineralization and chemical composition of the lake water was studied on 4 main transects from northern to southern coast:

- I transect – Choktal village-Akterek village;
- II transect – Cholpon-Ata town-Koltsovka village;
- III transect – Grigorievka village-Tamga village;
- IV transect – Orto-Uryukty village-Pokrovka village.

On each transect, water sampling was carried out at 3 stations at distances of 0.5 and 20 km from the northern coast and 5 km from the southern coast, up to a depth of 650 m. In 2002, water sampling was carried out at 3 stations at a distance of 15-20 km from Cholpon-Ata town up to depths of 300, 400 and 510 m, respectively. Coordinates of the sampling stations in the deep zone are as follows:

- Station 1, depth of 300 m – N42°32'57'', E77°04'08'';
- Station 2, depth of 400 m – N42°32'80'', E77°00'61'';
- Station 3, depth of 510 m – N42°32'04'', E77°05'56''.

Vertical distributions of chemical composition and pollutant contents in the deep zone water are summarized in Tables A-10, A-11.

Mineralization and chemical composition of deep zone water have small differences both on area and depth. The main type of water is chloride-sulfate-sodium. Sulfate/chloride

ratio (in mg-equiv) is close to 1. The Issyk-Kul water is known for its hydrochemical peculiarity and distinguishes it from other large reservoirs. The average value of total alkalinity of the lake water, caused by the presence of hydrocarbonate (HCO_3^-) and carbonate (CO_3^{2-}) ions, is ca. 5.23 mg-equiv. In comparison with other large reservoirs (the Balkhash and Baikal Lakes), the Issyk-Kul Lake has a high water alkalinity. From the basis of the data regarding chemical composition of the lake water during the period of 1998-2002, an average composition of Issyk-Kul Lake waters was determined using its specific gravity equals to 1.0052 and summarized in Table 2.

Table 2. Average chemical composition of the lake water

Ions	g/kg	mg-equiv/l
Ca^{2+}	0.115	5.72
Mg^{2+}	0.281	23.08
Na^+	1.525	66.29
CO_3^{2-}	0.023	0.77
HCO_3^-	0.267	4.37
SO_4^{2-}	2.144	44.65
Cl^-	1.606	45.30
Mineralization	5.961	

In 1935, the first research of the Issyk-Kul Lake water was made in 3 water samples by Matveev (1935). Mineralization is 5.823 g/kg, composition is chloride-sulfate-sodium, and chloride and sulfate concentrations were reported 44.70 mg-equiv/l and 44.03 mg-equiv/l, respectively. During the period of 1958-1983, the lake investigation was carried out under the guidance of Kadyrov (1986). On the base of analysis of 500 water samples, the lake water composition was determined as follows: mineralization is 5.968 g/kg, composition is chloride-sulfate-sodium, chloride and sulfate concentrations are 45.04 mg-equiv and 43.76 mg-equiv, respectively. Our results for 1998-2002 show that salt content in the water of the open zone of the lake is 5.961 g/kg; water composition is chloride-sulfate-sodium, chloride and sulfate concentrations are 45.30 mg-equiv and 44.65 mg-equiv, respectively. Comparison of our data and Kadyrov (1986) results show that for the period more than 20 years chloride concentration was raised to 0.26 mg-equiv or 9.23 g/kg and sulfates to 0.89 mg-equiv or 42.72 g/kg.

Among the pollutants, biogenic elements were determined in the lake water: nitrates (up to 0.103 mg/dm³), ammonium ions (0.010-0.037 mg/dm³), nitrites (0.002-0.006 mg/dm³) and phosphorus (up to 0.009 mg/dm³). Petroleum concentration in the surface layer of water was up to 0.001 mg/dm³ (Table A-11). Phenols and detergents were absent. Silica and fluorine contents were 1.8-2.1 mg/dm³ and 13.5-14.3 mg/dm³, respectively. Heavy metal contents in deep waters of the Issyk-Kul Lake are summarized in Table A-12.

The deep zone has a high self-cleaning ability. Human activity has not considerably influenced chemical composition of the lake water. The main reason is a large volume of water possessing high buffer capacity and converting capability. However, due to the constant reduction of the lake water mass, the self-purification ability of the lake waters decreases and, therefore, lake pollution will increase in future.

4. Suspended substances of river waters

The main source of mineral substances arriving in the Issyk-Kul Lake from the nourished area is the surface drain. According to their distribution in lake sediment, chemical elements are divided into two main groups: biogenic and terrigenous. Biogenic groups include

elements that accumulate in organisms (C, N, P, Br, I, and others) and components which form skeleton (CaCO_3 and SiO_2). Coastal zones are a reservoir for the biogenic group and this is a reason for increased biological productivity of the coastal zone (Strakhov, 1954).

The terrigenous group includes masses of hard deposit material entering from a water collected basin of running rivers. Before settling on the bottom, suspended substances pass a stage of suspended condition and experience an influence of drift, choppiness and vertical mixing of a reservoir. Therefore, materials entering with river water can be brought into another part of a lake. The terrigenous group includes the following elements: Fe, Cr, Al, Ti, Zr, Pb, Zn, Cu, Mn, Co, Ni.

Water samples for suspended substance determination were taken from 6 rivers (Toruaigyr, Tyup, Kurmenty, Aksu, Dzergalan, Ton). The amounts of suspended substances in river waters are:

River Toruaigyr – 1441.9 mg/l;
River Kurmenty – 413.9 mg/l;
River Tyup – 322.6 mg/l;
River Dzergalan – 359.1 mg/l;
River Akcu (Teplokluchenka village) – 185.7 mg/l;
River Ton – 3005.0 mg /l.

Predominated particles are dust particles (up to 45.7 %) and silt (up to 52.2 %), while the sand content is 1.6-2.9%.

Spectral analysis results of river suspended substances demonstrated that the following heavy metals present in the largest concentrations: titanium ($3 \cdot 10^{-1}$ - $4 \cdot 10^{-1}\%$), manganese ($7 \cdot 10^{-2}$ - $9 \cdot 10^{-2}\%$), strontium ($2 \cdot 10^{-2}$ - $3 \cdot 10^{-2}\%$), barium ($3 \cdot 10^{-2}$ - $4 \cdot 10^{-2}\%$) and zirconium ($1.5 \cdot 10^{-2}\%$). The highest concentration of manganese is in suspended matter of the Kurmenty River, strontium – of the Dzergalan River. The smallest content of titanium has been mentioned in suspended matter of the Aksu River, and zirconium – in the Toruaigyr River. Maximum concentration of titanium has been determined in all rivers ($2 \cdot 10^{-1}$ - $3 \cdot 10^{-1}\%$). River suspended matter of the Issyk-Kul hollow are mainly formed at the expense of elution from deposit rocks of mountain slopes by temporary streams. Therefore, the composition of suspended substances is characterized by chemical elements which compose deposit rocks.

5. Sediment of coastal zone of the lake

The sediments of the Issyk-Kul Lake have not been studied sufficiently. Therefore, during our work in 1998-2002, special attention was focused on sediment study. Bottom sediments of the Issyk-Kul Lake are formed by suspended material transferred by numerous rivers flowing down from mountain ridges and by temporary streams. Pollutants, that are the product of human activity in the Issyk-Kul basin, also arrive at the lake with the river drain. Compounds, which are not peculiar to the environment at all (phenol, petroleum, detergents, heavy metals and pesticides), belong to this group.

According to the results of granulometric analysis, dust particles are prevalent in sediments of the coastal zone of the lake (Table A-13). Dust content is 85.3 % in the Kyrsky Gulf sediment, 85 % in the Barskaun Gulf sediment, 82.2 % in the Lipenka inlet, 76 % in the Akterek Gulf, and its lowest content (28.8 %) is found in the Tyup Gulf. The highest content of silt particles is determined in the Kurmenty Gulf (44.9 %) and in the eastern coast bays (within 36-39 %), and the lowest one – in the Tamga Gulf (6 %). Sand particles are wide spread in sediment of the southern and western shores: the Kajisay Gulf (45.9 %), the Koltsovkа Gulf (36.8 %) and the Rybachy Gulf (18.1 %). In the coastal zone, clay deposits are typical for gulfs formed by riverbeds flood: the Kurmenty Gulf (12.2 %), Tyup Gulf (12.8 %) and Shirokaya Bay (11.9 %). According to the prevailing particle sizes, the gulfs can be put in the following

order: maximum sand content is found in the Kajisay and Koltsovka Gulfs, dust – in the Kursky and Barskaun Gulfs, silt – in the Kurmenty Gulf and clay – in the Tyup Gulf.

Sediment as a heterogeneous system consists of particles with various sizes whose presence is a result of sedimentation of substances arriving from different sources. Density and moisture capacity of sediment influencing the rate of chemical reactions and physico-chemical exchange processes depend on its granulometric composition (Kudrin, 1960). Chemical properties of sediment (the capacity for chemical binding, destruction and other transformations of substances arriving with the sediment) are caused by the chemical composition of its mineral part and the qualitative composition of organic substances (Tarnovsky, 1980).

Chemical composition of sediment is characterized by dissolved salt content within 3.81-17.71 g/kg (Table A-14). The highest salt concentrations were in sediments of the western and northern shores. The lowest salt content (4.18-11.35 g/kg) was found in sediment of the southern coast. Mineralization of sediment of the Tyup Gulf and its inlets was 12.22-16.94 g/kg and of the Dzergalan Gulf and its bays – 3.81-9.69 g/kg. In the Rybachy, Cholpon-Ata, Koltsovka, Ton and Akterek Gulfs, composition of sediment aqueous was chloride-sulfate-sodium-magnesium, and in most parts of the coastal zone of the lake – sulfate-chloride-sodium-magnesium that corresponds to the ratio of major ions in lake water. The tendency of salt content increase was observed with the increase of the sediment deposition depth. Accumulation of chlorides (by 1.5-1.6 times) and the decrease of sulfate (by 1.3 times) and hydrocarbonate (by 1.3-1.5 times) concentrations grew with the increase of depth. In the cation composition of water extract, contents of magnesium and sodium rise with the depth increase. Calcium content changed insignificantly.

Moisture content of sediment was within 31.4-70.8%, pH=7.12-8.02. The content of organic matter changed from 0.4 % (the Irdyk Bay) to 26.1 % (the Toruaigyr Gulf). Sediments of the northern coast of the lake (the Toruaigyr, Chyrpykty and Chok-Tal Gulfs) were considerably richer in organic matter than the southern coast. The main amount of organics in sediment forms due to plankton mortifying. Remains of the plankton organisms settle on the bottom and mix with terrigenous material composing the main part of sediments. Some amounts of organic matter also appear in the lake with suspended substances of river drain. A low content of organic substances in sediment is the evidence of weak development of plankton in the Issyk-Kul Lake.

There is no data related to the natural background of organic pollutants. The lake receives them with wastewaters. Petroleum is one of the most dangerous contaminants. Petroleum was found in the Rybachy and Kurmenty Gulfs (0.28-0.31 mg/kg). Phenol was found in the Cholpon-Ata Gulf (0.01 mg/kg). Concentrations of chloro-organic pesticides (GCCG) reached 0.07 mg/kg in the Tyup Gulf sediment.

Sediment is the main accumulator of pollutants in the lake. It accumulates different chemical elements arriving into the reservoir from the water-collected surface of the lake hollow and with wastewaters of industrial plants, rest houses and arable lands. Results of a spectral analysis of sediment show that metal concentrations in sediment can be put in regression sequence: Si>Ca>Al>Fe>Ti>Mn>Sr>Ba>Zr>Zn>Li>Ni>Cu>Pb>Co>Sn (Krumgalz and Karmanchuk, 1999, 2000, 2001, 2002). Lake sediment is characterized by high concentrations of alkaline elements (calcium, strontium and barium) that show evidence of carbonate formation processes typical to the lake. The prevalence of silica, aluminium and iron in sediment compositions confirms the terrigenous character of the lake sediment. Zinc and copper have the largest index of metal concentration in sediment (2.74 and 2.70, respectively). Lead, calcium, zirconium, cobalt and barium have a value of $k_c > 1$. $k_c = 1$ is typical for chromium, lithium and tin. Nickel, titanium, aluminium, silica and iron have a value of $k_c < 1$. They weakly accumulated by sediment owing to their low chemical activity under natural

conditions of the Issyk-Kul Lake and are partly assimilated by phytoplankton (Norms and Criteria, 1996).

Heavy metals in sediment according to the degree of their ecological danger are divided into 3 separate classes. In accordance with 17.4.1.02-83 SBST (SBST, 1985), toxic chemical elements are divided into 3 classes of hygienic danger:

1st class – arsenic (As), beryllium (Be), mercury (Hg), selenium (Se), cadmium (Cd), lead (Pb), zinc (Zn), fluorine (F);

2nd class – chromium (Cr), cobalt (Co), boron (B), molybdenum (Mo), nickel (Ni), copper (Cu), antimony (Sb);

3rd class – barium (Ba), vanadium (V), wolfram (W), manganese (Mn), strontium (Sr).

Copper, zinc, lead, cadmium and tin concentrations in the Issyk-Kul sediment are summarized in Table A-15. Lead is the most widespread element in sediment of the coastal zone. Its concentration changes from 2.45 (the Kursky Gulf) to 21.20 mg/kg (the Shiroky inlet). Maximum lead concentrations in the sediment are typical for the eastern and southern shores. Cadmium is present only in the sediment of the southern coast (0.01-0.31 mg/kg). Copper is widespread in the sediment along the entire length of the coastal zone of the lake. Its highest content was discovered in the sediment of the eastern part (17.92 mg/kg) and in some gulfs of the southern coast (Ak-Chiya, Koltsovka, Akterek Gulfs – 9.09-12.46 mg/kg). Zinc is absent in the eastern coast sediment. Its maximum concentration is 31.71 mg/kg in the southern gulf sediments and 1.35-9.25 mg/kg – in the northern and western ones. Tin is mainly widespread in the southern (0.74-3.86 mg/kg), western and northern coast sediments (0.56-2.81 mg/kg) and, in lower concentrations, in the eastern ones (0.67-1.08 mg/kg).

Analysis of heavy metal distribution shows their irregular spreading according to deposition depths. In the Rybachi and Ton Gulfs sediment, lead concentration increases with depth. In the Cholpon-Ata and Akterek Gulfs, it increases up to a depth of 20 m and then decreases. Lead concentration decreases with the depth in the Ak-Chiya Gulf. In the Koltsovka and Tamga Gulfs, a consistency in lead distribution according to sediment deposition depth could not be traced, but its maximum was observed at depths of 40 and 60 m. Copper concentration increases with the depth in the Rybachi, Ton, Tamga and Akterek Gulfs. In the Koltsovka, Ak-Chiya and Cholpon-Ata Gulfs, there was no such tendency for the growth of copper content. There is no definite consistency of zinc distribution in the sediment. Maximum zinc concentrations were found at a depth of 5 m in the Rybachi Gulf, at a depth of 20 m in the Cholpon-Ata and Koltsovka Gulfs and at a depth of 40.0 m in the Ton and Tamga Gulfs. The highest zinc concentration (53.40 mg/kg) was found at a depth of 20 m in the Ak-Chiya Gulf.

Sediment plays an important role in formation of water quality of the Issyk-Kul Lake water reservoir. Depending on the conditions, easily assimilated, hardly decomposed and often toxic compounds arrive with the sediment. Sediment contains high concentrations of heavy metals in comparison with water. Their highest concentrations are typical for the southern coast sediment.

6. Sediment of deep zone of the lake

Sediment study of the Issyk-Kul Lake was of great interest since all mineral substances arriving in the lake with river drain accumulate in the sediment composition. The main role in sediment formation process plays the material of terrigenous origin. A yearly drain of suspended substances is more than 900,000 ton including 800,000 ton in the east part of the lake and approximately 150,000 ton – in the west part (Sapozhnikov and Viselkina, 1960). An absolute rate of sediment accumulation is 15 g on 1 cm² for 1000 years on the basis of the lake area. The most recent data shows that a yearly decline of lake level is 4.6 cm, sediment accumulation at depths up to 200 m is 0.58 mm per a year and at depths of 300-668 m, 0.21 mm per a year.

In September 2001, four sediment cores were taken in the deep zone of the lake: at a depth of 70 m in the Cholpon-Ata Gulf, 110 m - near Kajisay, 125 m – in the Tosor Gulf and 185 m – in the Barskaun Gulf. Column tubes with lengths of 60 cm were used for sediment core sampling. Sediment was gray after sampling, and had strata of different tints. Dried sediments were similar and its flaky structure was imperceptible. The main components of sediment were clay and silt material. The data related to core study is summarized in Table A-16. A considerable part (64.1%) of sediment from a depth of 70 m was dust particles and 45 % - silt. Part of the sand increased to the central zone of the lake and was 2.8 % at a depth of 185 m. Dust particle content reached 76% and silt reached 46.8%. Maximum changeability of the sediment fraction ratios was observed at a shallow depth. This changeability is minimal in a deep zone. The upper 5 cm piece of the sediment was characterized by the increase of coarse fraction parts that was caused by the raise of terrigenous particle amounts coming in the lake. It was related with the broadening of irrigated land areas in the Issyk-Kul hollow.

The Issyk-Kul Lake situated in the inter-mountainous hollow is characterized by a weak development of the active sediment formation zone, which is narrow strip along its coast. In the lake, the zone of the passive sediment formation prevails and occupies the larger part of its bottom. The upper border of the passive sediment formation is at depths of 100-120 m and considerably increases in the gulfs (Sapozhnikov and Viselkina, 1960). In the cores, contents of dissolved salts were 6.21-9.40 g/kg in the Cholpon-Ata Gulf, 10.26-11.30 g/kg in the Kajisay Gulf, 6.51-9.21 g/kg in the Barskaun Gulf and 9.44-11.47 g/kg in the Tosor Gulf. Maximum salt concentrations were observed in the upper layers of sediments (0-5 cm) in all stations studied. Salt contents decrease with depth in all stations studied with the exception of the Cholpon-Ata Gulf: the highest mineralization (9.40 g/kg) was found in the layer of 15-20 cm and the lowest (6.21 g/kg) – at depth of 30-35 cm (Table A-17).

The sediments of the Issyk-Kul Lake are characterized by pH=7.16-7.80. In the Barskaun Gulf sediment, pH=7.30-7.35, in the Tosor Gulf – 7.18-7.21, in the Kajisay Gulf – 7.26-7.66, in the Cholpon-Ata Gulf – 7.39-7.80. Maximum value of pH (7.80) is typical for the Cholpon-Ata Gulf and minimum one – for the Tosor Gulf (7.18).

The cores have sulfate-chloride-sodium composition, and sulfate/chloride ratio (mg-equiv) was 1.12-1.65. Since concentrations of Na^+ , Cl^- , SO_4^{2-} and Mg^{2+} ions in the water were insufficient for the chemical precipitation of salts, these ions are absorbed on the terrigenous sediment arriving with suspended matter of the river runoff. According to the qualitative composition of dissolved salts in water and sediment, the Issyk-Kul hollow as a whole belongs to the area of development of sulfate-sodium greasing (History of the Sevan, Issyk-Kul, Balkhash and Aral Lakes, 1991).

The upper five cm pieces of the cores, characterized by high contents of coarse fractions, have the highest salt concentrations. In the bottom pieces, the decrease of dissolved salt content was observed. The salt content in the upper layer of the Barskaun Gulf sediment exceeded that at the core length of 45 cm by 1.41 times, in the Tosor Gulf – by 1.21 times, respectively, and in the Kajisay Gulf – by 1.10. In the Cholpon-Ata Gulf, decreasing relationship between salt concentration and core length was not observed at a depth of 70 m. The layers with mineralization of 6.21 g/kg and 6.89 g/kg, respectively, were situated between the layers with mineralization of 8.62 g/kg and 8.27 g/kg meaning that the zone of active sediment formation, for which processes of salt washing from the sediment at the rough lake are typical, were situated at a depth of 70 m in the Cholpon-Ata Gulf.

The content of organic matter determined by the ignition loss procedure changes from 9.6 to 25.1 % in the Cholpon-Ata Gulf, 9.9-17.3 % - in the Kajisay Gulf, 19.0-30.6 % - in the Barskaun Gulf, and 14.0-16.8 % - in the Tosor Gulf. Any definite regularity of organic matter distribution along the core was not observed. The highest concentration of organic matter was

typical for the Barskaun Gulf sediment. It was observed that the organic matter content in the sediment of the deep zone exceeds the coastal zone one by 2-4 times.

Heavy metal contents in the Issyk-Kul Lake deep zone sediment cores for 2001-2002 are summarized in Table A-18. Lead concentration was the highest in the deep zone sediment. Its content was 4.42-9.53 mg/kg in the Cholpon-Ata Gulf sediment, 9.34-16.90 mg/kg in the Kajisay, 6.40-7.64 mg/kg in the Tosor, and 3.74-7.90 mg/kg in the Barskaun Gulf. In the Cholpon-Ata Gulf sediment, lead concentration (9.40 mg/kg) was maximum in the upper layer of 0-25 cm, then it decreased with a core length and was 4.42-4.60 mg/kg in a layer of 50-55 cm. In the Kajisay sediment, the highest concentration (16.90 mg/kg) was determined at a core length of 20-30 cm, and was 10.50 mg/kg in the surface layer of 0-5 cm. In the Tosor Gulf sediment, lead concentration decreased from 7.64 to 6.40 mg/kg with the increase of core length. On the contrary, in the Barskaun Gulf sediment, lead content increased from 4.40 to 5.70 mg/kg with the raise of layer depths. Copper content in the Cholpon-Ata Gulf sediment was within 2.20-6.60 mg/kg, and it decreased with the increase of core length. The Kajisay Gulf sediment contained 5.70-6.90 mg/kg of copper, its maximum concentration was in a layer of 25-30 cm. The Tosor Gulf sediment had low copper content (0.27-0.37 mg/kg), and the Barskaun sediment – 0.21-1.40 mg/kg. Zinc concentration was also low in sediment: in the Cholpon-Ata Gulf – 0.00-0.98 mg/kg, in the surface layer of 0-5 cm – 0.23 mg/kg, and at a depth of 50-55 cm: 0 mg/kg. Zinc was absent in the Kajisay Gulf sediment and its concentration was 0.11-0.37 mg/kg in the Tosor Gulf. The Barskaun Gulf sediment contained 0.06-1.62 mg/kg of zinc, and its lowest content was in a layer of 0-5 cm. Tin was absent in the cores of the Cholpon-Ata and Barskaun Gulfs. The highest tin concentrations were found in the Tosor (2.76-3.30 mg/kg) and Kajisay (up to 1.17 mg/kg) Gulfs, and the surface layer of 0-5 cm contained its maximum content.

In August 2002, sediment sampling was carried out at 3 stations up to depths of 300, 400 and 510 m, respectively. Coordinates of the sampling stations are presented in Section 3. Sediment of the open zone from depths of 300-510 m were presented mainly by dust and silt particles (Table A-16). Dust content was 60.3% at a depth of 300 m, 59.4% - at a depth of 400 m and 50% - at a depth of 510 m, i.e., dust particle contents decreased while silt particle contents rose with depth: 39% (300 m), 36.1% (400 m), and 46.8% (510 m). Clay contents also decreased from 4.2% to 2.7%, sand part was about 0.5% at all depths mentioned. The deep zone sediments had pH=7.92-7.96 and a moisture content of 53.8-59.3%. Organic matter content was 13.3-14.0%. Salt concentrations were 6.84-7.13 g/kg. The sediment had a sulfate-chloride-magnesium-sodium composition (Table A-18). Sulfate/chloride ratio (mg-equiv) was 1.53-1.56. It should be mentioned that the sediment from depths of 300-510 m was characterized by high magnesium concentrations in comparison with sodium. Magnesium/sodium ratio was 1.89-1.97.

According to the classification by Levchenko (1953), sediment both of deep and coastal zones belong to the sulfate grade owing to the ratio of major ions. In sediment from depths of 300-510 m, contents of heavy metals especially copper and zinc were considerably lower than in cores from depths of 70-185 m (Table A-18). Cadmium was absent. Tin concentration was 0.76-0.94 mg/kg.

This material showed that the Kajisay Gulf cores contained the highest concentrations of lead and copper, the Barskaun ones and sediment samples from 300-510 m – zinc and the Tosor ones - tin. Comparison of the results on heavy metal contents in cores and sediments of the coastal zone showed that lead content in the Kajisay littoral zone reached 4.77 mg/kg and 16.90 mg/kg in the deep zone that was 4 times higher. In this region, copper was absent in the littoral sediment and its concentration reached 5.70-6.90 mg/kg in the cores. Zinc concentration was 5.57 mg/kg in the coastal zone of the Barskaun Gulf, and 0.06-1.62 mg/kg – in the cores. The sediment cores of the Kajisay and Cholpon-Ata Gulfs had accumulated lead and copper, and littoral sediments and cores contained about equal amounts of these elements. Littoral sediment

of the Barskaun Gulf was more saturated with lead than the deep ones, and inverse tendency was observed for copper.

Material on distribution of granulometric, salt compositions and heavy metals in the deep zones, summarized in this section, showed that the coastal zone of the southern shore was more polluted by zinc and lead than the deep zone, and about equal amounts of heavy metals were typical for both zones of the northern coast.

7. Sediment transport in the Issyk-Kul Lake

In August 1999, a joint team of Israeli (B. Krumgalz, B. Shteinman, S. Kaganovskii) and Kyrgyzstan scientists carried out the study of sediment transport in the Cholpon-Ata Gulf of the Issyk-Kul Lake. The main task was to train the Kyrgyzstan members of the scientific team to use the fluorescent tracer method developed at the Israel Oceanographic Research Institute.

Determinations of sediment dynamics with various radioactive, magnetic or fluorescent tracers have been used for many years. In this approach, labelled particles are placed in the stream where their movement was detected, enabling qualitative and quantitative assessments of the direction and velocity of the sediment transport. Natural radioactive tracers can also be used for these purposes (Shteinman et al., 1992; 1994), but have the disadvantage of having a weak and unselective signal while the placing of strong, "artificial" radioactive tracers into natural waterways is usually prohibited. In view of the drawbacks of the above methods, Prof. B. Shteinman developed the program of tagged fluorescent tracers to measure sediment transfer (Shteinman and Inbar, 1995). Fluorescent tracers have the advantage of being ecologically harmless; moreover, they can be detected with extremely high sensitivity. This method becomes increasingly versatile when particles are tagged with fluorescent dyes of different colours which can also be "programmed" to last for varying periods of time.

Sediment was sampled from the Cholpon-Ata River. After thorough air-drying, it was mixed with one of the following dyes to obtain particles with coloured fluorescence as indicated: rhodamine (red fluorescence), auramine (yellow), and eosine (orange). Depending on the specific dye solutions, a special fixative was added. Depending on the fixative, the "lifetime" of these particles could be varied from 10 days to 6-7 months. The tagged fluorescent sediment was replaced on the lake bottom in the Cholpon-Ata Gulf. After 3 days, samples from the lakebed were taken at appropriate distances from the sampling site and analysed for their content of tagged fluorescent particles. All sampling sites were precisely marked and mapped. The collected samples were carefully air-dried and taken to Israel where the quantitative analysis of colored fluorescent tracers was conducted. The analysis of the results led to the following conclusions:

1. Sediment transport from east to west was dominant in the Cholpon-Ata Gulf according to the current direction.
2. Sediment transport near the shore with a depth of 5 m swerved to the bay and continued its movement along the shore. The sediment flow gradually decreased due to sediment accumulation on shore.
3. The zone of movement for underwater sediment reached depths of 15 m.

In 2001, the study of sediment transport in the Cholpon-Ata Gulf using fluorescent tracers was continued. However, we could not send the samples for the analysis of tagged particle contents to Israel due to customs problems. Continuation of works on tracer use for determination of river drain suspended matter and processes of sediment formation in the Issyk-Kul Lake were of scientific interest and had practical importance.

VI. POLLUTANT LOADING IN THE LAKE

1. Anthropogenic component of natural waters

The Issyk-Kul Lake is one of the largest high-mountainous lakes of the continental origin. The salty lake and freshwater rivers are common ecological system (Table A-19). River and lake waters with their chemical composition belong to the sulfate grade of waters. Sediment of coastal and deep zones of the lake are characterized by the prevalence of sulfates in chemical compositions of water extract and belong to the sulfate grade.

The main source of the contaminants in the lake was river drain and partly ground waters and wastewaters. In 2001, wastewater volume was $55.7 \cdot 10^6 \text{ m}^3$ in the Issyk-Kul hollow including $45.4 \cdot 10^6 \text{ m}^3$ discharged in the rivers and lake and $10.0 \cdot 10^6 \text{ m}^3$ used for irrigation. The influence of human activity on natural waters results not only in the appearance of components, which are not characteristic to the environment, such as phenols, detergents, petroleum, heavy metals, but also in changing major ion contents. The economic activity led to metamorphization of river water from hydrocarbonate-calcium type to sulphate-sodium type. The development of irrigation has a great influence on changes of ion composition of the river drain. One method of evaluating pollution of river water is the consideration of an anthropogenic component, which is separated from the total river drain. The value of the anthropogenic component was calculated as follows:

$$R_{\text{an}} = R_i - R_{\text{back}}, \quad (3)$$

where R_{an} is an anthropogenic component, R_i is an ion drain for the calculated period, R_{back} is a background one. The calculation was conducted on the basis of the ion composition data of the Tyup, Dzergalan, Karakol, Chon-Kyzylsu Rivers's water. In accordance with the data of the Hydrometeorology Service, water drain of these rivers for the mentioned period was $49.53 \text{ m}^3/\text{s}$. Natural background composition was determined as an average one from the chemical composition of river headwater (Table A-20). An anthropogenic component of the ionic drain for the Issyk-Kul hollow reaches $80.14 \cdot 10^3$ tons per year. The modern scales of human activity in the Issyk-Kul Lake basin led to the increase of river ionic drain by 33%. An anthropogenic component in river drain reaches 79%. Pollution with copper and zinc was absent as their contents in river water correspond to background concentrations. The content of pollutants in river water was not constant and changed occasionally.

2. Pollution level of the Issyk-Kul natural waters

Anthropogenic component for the natural waters of the Issyk-Kul hollow was calculated on the basis of our experimental data for the period of 1985-1992 (Table A-21). The results show that the pollution index (PI) of the Issyk-Kul rivers exceeded the background content by 52.52 times, the coastal zone – by 57.68 times, and ground waters – by 47.38 times. In water of artesian wells, contents of detergents and petroleum exceeded the background values by 5 times. PI for the spring water was 12.66. For evaluation of pollution level of the water resources, maximum permissible concentration (MPC) norms for separate types of pollutants were practically used. Since the Issyk-Kul Lake is a reservoir of commercial importance, MPC standards for the fish-farming reservoirs were used for the pollution level control. Data regarding the pollution level of natural waters of the hollow is presented in Table A-22.

MPC levels of pollutants were considerably higher than background contents, therefore, the sum index for river water pollution was less than the anthropogenic component by 3.75 times, ground waters - by 2.54 times, water of the coastal zone – by 3.43 times. On the contrary, the sum index for the deep zone was higher than the technogenic part of the loading by 2.7

times. In the deep zone of the lake, only heavy metals were accumulated, while the organic pollutants (phenols, detergents, petroleum) were oxidized.

Heavy metals, petroleum, organic substances and nitrogen compounds are the main contaminants of the Issyk-Kul basin environment. The most polluted regions were the Tyup, Dzergalan, Karakol, Aksu, Tamga and Barskaun Rivers and the coastal zone (the Rybachy, Tyup, Dzergalan, Kurmenty, Koltsovka and Ton Gulfs). The decline of the lake level hastened the degradation of its ecosystem. The control for the contaminant amounts discharged with the filtration and drainage waters was not conducted.

3. Sum index of pollution of the Issyk-Kul waters

Human activity strongly affects the process of sediment accumulation. Different substances of anthropogenic origin arrive at the sediment that influences the ingredient transformation processes in sediment. The exchange process between water and sediment is permanent. The sediment can be the source of repeated pollution of water if the ratio of toxic compound concentrations in water and sediment is less than 1. The main pollutants are petroleum, phenols, ammonium salts, nitrates and metal compounds. Heavy metal contents in lake sediment can be compared with their average content in the precipitation rocks of a region or in other lakes. However, this criterion is a relative one since it does not take into consideration any peculiarities of the region studied. Therefore, the data of chemical element clarks in sediment was necessary for the evaluation of the degree of anthropogenic pollution of the lake. No literature data about clarks in Issyk-Kul lake sediment was found. The problems of content and distribution of microelements in the Issyk-Kul Lake sediment have never been studied before. Therefore, we will make the first attempt in clarifying the problem of heavy metal origin in the Issyk-Kul Lake sediment. Is the heightened metal content in the sediments a result of anthropogenic loading or is the appearance of metal caused by natural factors?

The structure of the Issyk-Kul hollow promotes that both river waters and all polluted waters flow into the lake causing its pollution. The decline of the lake level also causes the decline of the level of underground waters entails that in turn causes the drying of the coastal zone and even desertification of the territory. After USSR disintegration, industrial activity was interrupted in the Issyk-Kul basin. Anthropogenic loading connected with the human activity decreased. The use of fertilizers and chemical pest-killers was reduced in agriculture, and therefore, the content of toxic ingredients in the melioration drains decreased. Thus, the main pollutant source of the lake was the discharges of towns, villages, boarding and rest houses situated on the Issyk-Kul Lake coast. Broken purifying equipment, obsolete technology of purification and the absence of sewer systems in the villages resulted in the arrival of non-purified drains into the lake, and to pollution of the coastal zone by ammonium salts, nitrates, detergents and petroleum. But there were no industrial or municipal available sources of lake pollution by heavy metals. Therefore, for evaluation of anthropogenic components in sediment, the ratio of heavy metal contents in coastal zone sediment C_i and at the background value C_b was used. Pollution level was evaluated as the sum of index of pollution (SIP) as follows:

$$PI = \sum K_c \cdot n \quad (4)$$

$$K_c = C_i / C_b \quad (5)$$

where C_i and C_b are concentration of the "i" element in sediment and its background value and "n" is the number of summation elements. For the pollution index of the sediment, the following gradations were determined (Brekhovskikh, 2001):

minimum pollution	0-10
medium	11-15
high	>15

Background values of heavy metals were determined by their contents in suspended substances arriving in the lake with river drainage. Heavy metal concentrations were determined by the spectral method in suspended substances of the Toruaigyr, Cholpon-Ata, Tyup, Dzergalan and Ton Rivers (Table A-23). Values of background concentrations of toxic metals were as follows: 2.66 mg/kg for copper, 4.00 mg/kg for zinc, 5.60 mg/kg for lead, 0.00 mg/kg for cadmium and arsenic and 0.30 mg/kg for tin. Heavy metal contents in the river and lake waters were lower than in the suspended substances. In the coastal zone sediments, background concentration of zinc was exceeded by 3 times, lead – by 2.5 times, cadmium – by 0.14 times and tin – by 0.94 times. Using this data, K_c and PI were calculated and presented in Table A-24. The highest pollution level of the lake sediment was typical for the Ak-Chiya (18.68), Koltsovka (16.17), Rybachy (14.13) and Dzergalan (13.70) Gulfs and the lowest one – for the Pokrovsky Gulf (5.73).

In accordance with the gradation mentioned above, the sediment had a high (the Ak-Chiya and Koltsovka Gulfs) and medium level of heavy metal pollution (the Rybachy, Dzergalan and Cholpon-Ata Gulfs, the Chisty, Shiroky, Nikolaevsky, Lipenka, Barskaun, Ton, Akterek and Kajisay inlets). The rest of the coastal zone had a minimum pollution level. In the deep part of the lake, sediment had a medium level of pollution near the Tosor (11.63) and the rest of the lake bottom had a minimum level. The most widespread metals of the sediment were tin, lead and copper. Zinc was present in a small amount, and cadmium was absent. The geochemistry of heavy metals in the Issyk-Kul sediment was done accordingly to Osmonbetov (1999) and Tursungaziev (1998). Molybdenum and tungsten were widespread in the precipitation rocks of the Kungei Ala-Too (the northern coast of the lake) and lead – in the region of the Tyup-Dzergalan zone. Precipitation rocks of the Terskey Ala-Too (the southern coast of the lake) contained zinc, lead and tin, in rocks of the Barskaun River upper course – lead and zinc and of the Chon-Kyzylsu River – tin. Lead was widespread in composed rocks of the western part of the lake.

Geochemistry of metal distributions in precipitation rocks and sediments was not similar. Thus, in the western part of the lake, lead was prevalent in the mountainous rocks and copper – in sediment. Precipitation rocks of the northern coast were enriched by manganese and tungsten, and sediment contained high concentrations of tin. In the eastern part of the lake, tin and lead were prevalent in composed mountainous rocks, and copper and lead – in sediments. On the south of the lake, heightened contents of lead, zinc and tin were found in the rocks and zinc and lead – in the sediment. Considerable role of heavy metals distribution on the lake bottom must belong to the streams, which had the prevalent direction from the east to the west. Suspended terrigenous particles and pollutants were transferred in this direction. Thus, data of heavy metal contents in the sediments showed that the highest technogenic loading on the lake was in the Dzergalan Gulf (the eastern part), the Cholpon-Ata Gulf (the northern part) and the Ak-Chiya, Koltsovka, Tosor, Barskaun and Kajisay Gulfs (the southern part).

Since the Issyk-Kul Lake level has a total tendency to the decline for the last century, this fact put a negative mark on the ecological state of the lake in the conditions of its entire natural isolation. Evaluation of ecological condition of surface waters and lake sediment on 38 inorganic and organic compounds showed that the river and lake waters were weakly and moderately polluted. According to the value of the sum index of pollution, the lake sediments were characterized as highly (the Ak-Chiya and Koltsovka Gulfs) and medium polluted (the Rybachy and Dzergalan Gulfs) sediments. Besides high natural metal concentrations due to the drift from ore deposits situated on the Issyk-Kul mountains, anomalously high contents of lead, copper and tin were found in the coastal zone sediment and zinc – in the southern coast sediments. Thus, ecosystem of the Issyk-Kul Lake was under the anthropogenic loading. The main sources of pollution were transport, towns, sanatoriums, rest houses, factories, irrigated agriculture and farms. The environment could not self-purify at the present regime of drains.

This problem could be solved by the development of new, ecologically safe technologies on the factories, transport and municipal and private sector of economy. The process of ecological pollution must be supported by the corresponding ecological legislation.

Our suggestions for the improvement of water-ecological situation in the Issyk-Kul hollow are follows:

- 1) establish ecologically well-founded limits of use for natural water resources and calculate fair payment for their use for each enterprise;
- 2) do not allow a placement of water-capacious and water-polluting enterprises in the Issyk-Kul hollow;
- 3) stop discharges of polluted waters into the rivers and lake and increase the purification degree on the water-protecting installations;
- 4) conduct the reconstruction of existing water supply and drainage systems in settlements and build new ones in places where they are absent;
- 5) create the monitoring systems for the water quality observation.

VII. CONCLUSIONS

1. There are more than 60 rivers in the Issyk-Kul Lake basin. Most of them are used entirely for irrigation and household needs. In the western part of the lake, river net is developed very poorly, river drain of the northern coast is $479.7 \cdot 10^6 \text{ m}^3$, $1992.4 \cdot 10^6 \text{ m}^3$ – of the eastern one, and $1105.1 \cdot 10^6 \text{ m}^3$ of the southern one. The highest anthropogenic loading in river waters occurred in summer due to resort activity. During spring and fall, the main pollutants were nitrogen compounds (nitrates, ammonium) that arrive from irrigated tracts of land. During the summer, the main source of pollution was non-purified waters of villages, towns and sanatoriums. Phenols, heavy metals and petroleum appeared in the river water at this season. Transformation of river drain quality can be shown on mineralization increase according to river lengths and on exceeding MPC norms for petroleum, phenols, detergents, heavy metals, nitrates and ammonium ions by 2-4 or even 10-20 times.
2. Coastal zone of the lake was characterized by depths of 60-100 m, and has 28 gulfs, inlets and bays. Water mineralization of this zone depended on volume of river drain. It is within $2,420\text{-}5,960 \text{ mg/dm}^3$. In the coastal zone water, nitrate contents exceeded MPC norms by 2.1-3.1 times and phenol contents – by 3-12 times. Contents of following heavy metals exceeded permissible levels: copper – by 2-7 times, zinc – by 4-5 times, tin – by 7-14 times (in the Tamga Gulf – by 38 times, in the Akterek Gulf – by 42 times) and arsenic – by 1.1-1.6 times. Concentrations of lead and cadmium did not exceed MPC values in the waters of the coastal zone. Fluorine concentration was within $5.7\text{-}14.3 \text{ mg/dm}^3$ and silica – within $1.0\text{-}2.0 \text{ mg/dm}^3$. The Rybachy, Dzergalan, Tyup, Akterek, Tamga, Koltsovka and Kurmenty Gulfs were found to be influenced by the largest anthropogenic loading.
3. The deep central part of the lake (with depths from 100 to 668 m) was characterized by easy vertical and horizontal water circulation, therefore, its mineralization (5.961 g/kg) and chemical composition (chloride-sulfate-sodium) was identical throughout the lake. The deep zone had high self-cleaning ability. Human activity has not considerably influenced chemical composition of the lake water.
4. Surface drain was the main sources of mineral substances arriving into the Issyk-Kul Lake from nourish areas. The lake receives $322.6\text{-}3,005 \text{ mg/dm}^3$ of suspended matter from the river drain. Prevalent particles of the alluvia were dust (45.7%), silt (52.2%) and sand (1.6-2.9%). Titanium, manganese, strontium, barium, zirconium and other elements composing precipitation rocks of river drain formation zone were present in the suspended matter composition in the largest amount.

5. Chemical composition and pollution level of modern sediment of the Issyk-Kul Lake has never been studied before. Therefore, we paid our special attention to the sediment studies during our works conducted on the lake. Granulometric composition of the coastal zone sediment was dust (28.8-85.0%), silt (6.0-44.9%), sand (18.1-45.9%) and clay (11.6-12.8%). Maximum sand content was in the Koltsovka and Kajisay Gulfs, dust – in the Barskaun and Kurski Gulfs, silt particles – in the Kurmenty bay and clay – in the Tyup Gulf. Chemical composition of sediment was characterized by dissolved salt contents within 3.81-17.71 g/kg. Sediment of western and northern shores of the lake had the highest mineralization values. Sediment composition was sulfate-chloride-sodium that corresponds to the ratio of major ions in the coastal zone water. Moisture content of sediment was 31.4-70.8% and pH=7.12-8.02. Concentration of organic substances was 0.4-26.1%. Sediment of the northern coast of the lake was richer in organic matter than the southern one. Sediment of the Rybachy and Kurmenty Gulfs contained petroleum (0.28-0.31 mg/kg), of the Cholpon-Ata Gulf – phenol (0.01 mg/kg) and of the Tyup Gulf – GCCG pesticide (0.07 mg/kg). Sediment was characterized by high concentrations of alkaline elements (calcium, strontium and barium) that showed evidence of carbonate formation processes typical to the lake. Prevalence of silica, aluminium and iron in sediment compositions confirmed the terrigenous character of the lake sediment.
6. Sediment was the accumulator of heavy metals, which were a characteristic of pollution level and an index of anthropogenic load on the reservoir. Lead was the most widespread metal in sediment. Its maximum concentrations (up to 21.20 mg/kg) were found in the eastern and southern coast sediments. Copper was widespread throughout the coastal zone. Its maximum content (up to 17.92 mg/kg) were also discovered in the eastern and southern coast sediment. Zinc was absent in the eastern shore sediment, its concentration was 31.71 mg/kg in the southern one and 1.35-9.25 mg/kg in the northern and western ones. Some amounts of tin (0.56-3.86 mg/kg) were present throughout lake sediment. Cadmium (0.01-0.31 mg/kg) was detected only in the sediment of the northern and southern coasts. Heavy metal concentrations in sediment were higher than in the lake water. Their highest values were typical for the southern coast sediment.
7. Sediment of the deep zone taken in the Cholpon-Ata, Kajisay, Tosor and Barskaun Gulfs at depths of 70-185 m by column tubes, and 300, 400 and 510 m were dust particles (up to 76%), silt particles (up to 46.8%), clay (2.7-4.2%) and sand (ca 0.5%). In cores, salt contents were 6.21-11.47 g/kg, and at larger depths (300-510 m), it decreased to 6.84-7.13 g/kg. According to the qualitative composition of dissolved salts in sediment, the Issyk-Kul Lake belongs to the area of sulfate-sodium salinization. In the upper layers of sediments, dissolved salt contents were higher by 1.2-1.4 times than in the lower situated layers. Sediment of the deep zone was richer by 2-4 times in organic matter than the coastal one.
8. In the deep zone sediment, among heavy metals, lead was the most widespread element (4.42-16.90 mg/kg). Copper concentration was 0.21-6.90 mg/kg. Maximum contents of lead and copper were discovered in the Kajisay Gulf sediment. Zinc concentration was 0.00-1.62 mg/kg, and its maximum value was detected in the Barskaun Gulf sediment. Tin concentration reached 0.00-3.30 mg/kg, and its maximum value was found in the Tosor Gulf sediment. Comparisons of data of heavy metal contents in sediments of deep and coastal zones showed that southern shore sediment were richer in zinc and lead and, for the northern coast, similar metal concentrations were typical for both zones.
9. The sediment transport from east to west dominated in the Cholpon-Ata Gulf and was according to the current water direction. The zone of underwater sediment movement reached a depth of 15 m.
10. The ecological conditions of the Issyk-Kul Lake began to attract scientific attention over the past several years. Two aspects related to lake ecology should be discussed. First, lake level

constantly decreases. Over the past 70 years, the lake level decreased for ca. 3.5 m. During the past time, regression of lake level was 4.6 cm per year. Due to agricultural development in the Issyk-Kul area, the amount of water used for irrigation increased constantly: in 1966, 9% of river drain was used for irrigation purposes; in 1982, the percentage was already 34 %. In 1997 it reached 43%. The second aspect was related to economic activity in the Issyk-Kul area, namely, the pollution of lake water caused by intensive development of tourism, construction, irrigation agriculture and cattle breeding. The formation of ecological conditions of the Issyk-Kul Lake basin was influenced by numerous natural and anthropogenic factors. Natural factors, which determined the chemical composition of river waters on the given territory, were practically unchangeable for a small interval of time. Anthropogenic factors such as the industrial and municipal wastewaters and drains from arid land led to the disturbance of the natural ecological balance of "rivers-lake-sediment" system and influenced on the ecological conditions of the Issyk-Kul Lake.

11. The modern scales of human activity in the Issyk-Kul Lake basin led to the increase of river ionic drain by 33 %. An anthropogenic component in the river drain reached 79 %. Analysis of experimental data showed that the pollution level of natural waters of the Issyk-Kul Lake was considerably higher during the period of 1985-1992 than now. The pollution level of the river waters exceeded the MPC norms 14 times, the coastal zone water 16.8 times, and deep zone water 8 times. The water of springs and artesian wells and ground waters were also polluted (4-5 MPCs). During the period of 1998-2002, the pollution level decreased due to economic problems. However, the continuing decline of the lake level, absence of water-supply and drainage systems in the settlements, the low purification degree of effluents at purifying constructions in Rybachy, Cholpon-Ata and Karakol towns, sanatoriums and rest houses, expansion of building and transport service led to the impossibility of self-purification of river and lake waters at the present regime of drains.
12. Modern evaluation of ecological conditions of the Issyk-Kul Lake was given according to the value of the sum index for pollution of the coastal and deep zone sediment by heavy metals. According to the organic contaminant contents, river drain and the Issyk-Kul water are weak and moderate polluted waters. The sediment of the coastal zone were classified as follows:
 - a) minimum polluted with $PI=0-10$ (the Pokrovsky, Tamga, Tyup< Chok-Tal, Kursky, Dolinka Gulfs and others);
 - b) medium polluted with $PI=11-15$ (the Rybachy, Dzergalan, Akterek, Chisty, Barskaun and Ton Gulfs);
 - c) high polluted with $PI>15$ (the Ak-Chiya and Koltsovka Gulfs).

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IX. MANAGEMENT

During the period of 01.05.1998-31.07.2003, 17 scientific expeditions for the sampling of water and sediment in the area under study were carried out. Chemicals, small equipment (electronic balances, portable pH-meter, photo-colorimeter, e-Map DX receiver, distiller) and various apparatus (AA-2 analyzer, ARP furnace, Xerox, printer HP Laser, processor, scanner, corer and others) were purchased for the Scientific and Research Institute of Irrigation (Bishkek, Kyrgyzstan).

All collected samples of water and sediment were analyzed for salt and granulometric composition. Biogenic elements, organic pollutants and heavy metals (Fe, Cu, Zn, Cd, Sn, Pb, As) were also determined. Thus, all the work planned by the research program for this period has been completely fulfilled.

On the basis of collected data, 9 scientific and financial reports including 4 semi-annual reports, 4 annual ones and 1 final report for the whole research period have been prepared.

X. COLLABORATION

The current project was fulfilled under close collaboration between the Israel Oceanographic & Limnological Research Institute and the Kyrgyz Scientific and Research Institute of Irrigation on all stages of the study. One of the examples of this type of collaboration was the training of Dr. A. Karmanchuk, S. Belokon and L. Kanygina on the new method of sediment transport determination by use of fluorescent tracers. The training course was conducted by Prof. B. Krumgalz, Prof. B. Shteinman and S. Kaganovsky who came to Kyrgyzstan especially for this purpose. This method was used by the Kyrgyz side for the study of tagged tracer transport in the Cholpon-Ata Gulf.

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XII. APPENDIX

Table A-1. Determination of experimental error

Ions	Standard value	Average value	Absolute error	Relative deviation, %
Ca	58.5	58.6	0.1	1.23
Mg	24.0	24.0	0.0	1.77
Na	90.0	90.15	0.15	0.74
SO ₄	317.5	317.8	0.3	0.33
Cl	79.0	78.35	0.65	1.32
Zn	0.104	0.106	0.002	2.88
Cu	0.110	0.109	0.002	2.03
Pb	0.084	0.082	0.002	3.76

Table A-2. Parameters of Issyk-Kul Lake waters

Parameter	1975-1982	1985-1992	1998-2002
Water temperature, °C	2.80-22.20	2.60-23.00	4.40-22.00
	2.40-22.20	3.90-21.40	4.80-19.50
pH	6.50-9.98	8.05-8.78	8.55-8.95
	8.13-9.68	8.57-8.95	8.55-8.90
Transparency, m	0.00-23.00	0.30-19.00	0.50-13.00
	1.50-34.00	8.00-35.00	6.00-15.00
Dissolved oxygen, mg/dm ³	4.74-15.02	6.25-14.18	7.52-9.83
	6.24-10.50	7.08-9.78	7.90-9.64
Concentration of dissolved mineral substances, %	2.20-5.70	2.60-5.90	2.60-5.90
	4.40-6.30	5.70-6.00	5.60-5.90
BOC ₅ , mg O ₂ /dm ³	0.00-10.54	0.29-2.14	0.09-1.97
	0.02-5.38	0.29-2.14	0.18-2.07
Petroleum, mg/dm ³	0.00-0.69	0.00-0.02	0.00-0.03
	0.00-0.37	0.00-0.03	0.00-0.03
Phenols, µg/dm ³	1.00-3.00	0.00-2.00	0.00-12.00
	1.00-7.00	0.00-2.00	0.00-1.00
Detergents, mg/dm ³	0.00-0.08	0.00-0.04	0.00-0.011
	0.01-0.04	0.00-0.02	0.00-0.01
Zinc, µg/dm ³	0.00-40.00	0.00-77.00	0.00-10.00
	0.00-30.00	0.00-46.00	0.00-7.00
Copper, µg/dm ³	0.00-9.00	0.00-14.00	0.00-2.00
	0.00-26.00	0.00-4.00	0.00-2.00

Note: in numerator - data related to littoral zone, in denominator - data related to pelagial zone.

Table A-3. Chemical composition of river waters of the Issyk-Kul area (1998 - 2002)

River		Concentration (in numerator – mg/dm ³ , in denominator – mg-equiv)							Mineralization, mg/dm ³
		Ca ²⁺	Mg ²⁺	Na ⁺ +K ⁺	HCO ₃ ⁻	CO ₃ ²⁻	SO ₄ ²⁻	Cl ⁻	
Western coast	Turasu	134.0	21.4	3.7	315.3	-	141.6	17.7	633.7
		6.69	1.76	0.16	5.17		2.94	0.50	
Northern coast	Toruaigyr	22.0	8.5	12.0	79.3	-	42.8	4.61	169.2
		1.10	0.70	0.52	1.30		0.89	0.13	
	Chon-Aksu	37.5	10.7	35.3	107.6	-	108.7	9.0	308.8
		1.87	0.88	1.53	1.76		2.25	0.25	
	Aksu, (Semionovka village)	34.7	5.85	9.35	95.3	-	41.2	6.9	193.5
		1.73	0.48	0.41	1.56		0.86	0.19	
	Oital	22.0	8.5	28.8	97.6	-	63.4	4.61	224.9
		1.10	0.70	1.25	1.60		1.32	0.13	
	Kuturga	28.4	5.2	12.9	78.5	-	39.6	10.5	175.1
		1.42	0.43	0.56	1.29		0.82	0.30	
	Kurmenty	28.4	2.9	11.4	65.5	-	44.0	5.2	157.4
		1.42	0.24	0.50	1.07		0.92	0.15	
Eastern coast	Tyup	78.7	6.4	14.5	200.0	-	62.0	9.1	370.7
		3.93	0.53	0.63	3.28		1.29	0.26	
	Aksu river, (Teplokluchenska village)	26.5	3.0	8.2	70.7	-	24.9	8.4	141.7
		1.32	0.25	0.36	1.16		0.52	0.24	
	Dzergalan	36.1	6.1	7.1	73.2	-	55.3	9.2	187.0
		1.80	0.50	0.31	1.20		1.15	0.26	
	Karakol	26.5	4.5	11.0	86.0	-	28.5	5.9	162.4
		1.32	0.37	0.48	1.41		0.59	0.17	
	Dzety-Oguz	50.9	6.5	2.3	120.5	-	28.4	21.3	229.9
		2.54	0.53	0.10	1.98		0.59	0.60	
	Chon-Kyzylsu	37.5	7.7	6.6	98.4	-	45.1	8.4	203.7
		1.87	0.63	0.29	1.61		0.94	0.24	
Southern coast	Dzuuka	46.1	7.6	18.1	135.2	-	59.3	9.2	275.5
		2.30	0.63	0.79	2.22		1.23	0.22	
	Chon-Dzargylchak	39.5	2.3	10.3	96.8	-	38.6	7.6	199.1
		1.97	0.19	0.45	1.59		0.80	0.21	
	Barskaun	36.1	10.9	12.0	109.8	-	61.5	5.0	235.3
		1.80	0.90	0.52	1.80		1.28	0.14	
	Tamga	55.6	6.9	4.6	147.8	5.1	35.2	8.5	263.7
		2.77	0.57	0.20	2.42	0.17	0.73	0.24	
	Tosor	53.8	5.7	7.2	136.9	2.3	36.7	13.3	255.9
		2.68	0.47	0.31	2.24	0.08	0.76	0.38	
	Keklikbulak	95.2	19.3	19.1	287.4	13.7	62.6	24.8	522.1
		4.75	1.59	0.83	4.71	0.46	1.30	0.70	
	Ton	43.1	5.1	47.0	177.9	-	45.6	11.7	330.4
		2.15	0.42	2.04	2.92		0.95	0.33	
	Aksai	81.1	12.8	0.9	204.0	9.1	57.5	10.6	376.0
		4.05	1.05	0.04	3.34	0.30	1.20	0.30	
	Akterek	95.2	19.3	0.5	241.1	4.6	84.4	17.7	462.8
		4.75	1.59	0.02	3.95	0.15	1.76	0.50	

Table A-4. Contents of biogenic elements and organic pollutants (mg/dm³) in river waters of the Issyk-Kul hollow (1998-2002)

River	N _{NO₂⁻}	N _{NO₃⁻}	N _{NH₄⁺}	P _{total}	Detergents	Petroleum	Phenols
Western coast							
Turasu	0.024	0.000	0.000	0.000	0.000	0.002	0.000
Northern coast							
Toruaigyr	0.020	0.370	0.270	0.040	0.000	0.000	0.000
Chon-Aksu	0.006	0.170	0.000	0.000	0.005	0.002	0.004
Aksu, Semionovka village	0.028	0.160	0.000	0.001	0.005	0.002	0.004
Oital	0.000	0.190	0.000	0.044	0.005	0.001	0.000
Kuturga	0.007	0.100	0.000	0.000	0.018	0.000	0.000
Kurmenty	0.011	0.100	0.060	0.010	0.010	0.001	0.000
Eastern coast							
Tyup	0.014	0.350	0.150	0.009	0.008	0.003	0.000
Aksu river, Teplokluchenka village	0.008	0.270	0.040	0.005	0.013	0.002	0.001
Dzergalan	0.008	0.260	0.160	0.013	0.020	0.002	0.001
Karakol	0.005	0.290	0.000	0.002	0.018	0.005	0.002
Dzety-Oguz	0.004	0.050	0.000	0.000	0.000	0.000	0.002
Chon- Kyzylsu	0.007	0.070	0.040	0.007	0.009	0.001	0.004
Southern coast							
Dzuuka	0.000	0.190	0.000	0.003	0.005	0.000	0.000
Chon- Dzargylchak	0.008	0.240	0.000	0.004	0.000	0.002	0.001
Barskaun	0.008	0.320	0.160	0.007	0.000	0.000	0.000
Tamga	0.006	0.130	0.030	0.007	0.010	0.002	0.001
Tosor	0.004	0.340	0.000	0.017	0.005	0.001	0.000
Keklikbulak	0.000	0.010	0.000	0.001	0.000	0.000	0.000
Ton	0.005	0.170	0.200	0.033	0.007	0.003	0.000
Aksai	0.000	0.000	0.000	0.003	0.010	0.000	0.000
Akterek	0.000	0.040	0.320	0.000	0.000	0.001	0.002

Table A-5. Heavy metal contents (mg/dm³) in river waters of the Issyk-Kul hollow (1998-2002)

River	Fe	Cu	Zn	Pb	Cd	Sn	As
Western coast							
Turasu	0.052	0.002	0.001	0.002	0.00	0.000	0.000
Northern coast							
Toruaigyr	0.000	0.004	0.004	0.000	0.000	0.000	0.000
Chon-Aksu	0.040	0.002	0.000	0.001	0.000	0.000	0.001
Aksu, Semionovka village	0.016	0.001	0.002	0.003	0.000	0.000	0.000
Oital	0.000	0.002	0.009	0.002	0.000	0.000	0.000
Kuturga	0.000	0.002	0.002	0.001	0.000	0.000	0.000
Kurmenty	0.015	0.013	0.002	0.007	0.000	0.000	0.000
Eastern coast							
Tyup	0.020	0.010	0.003	0.003	0.000	0.000	0.000
Aksu river, Teploklu- chenka village	0.010	0.047	0.003	0.000	0.000	0.000	0.000
Dzergalan	0.010	0.012	0.005	0.000	0.000	0.000	0.000
Karakol	0.016	0.003	0.003	0.002	0.000	0.000	0.000
Dzety-Oguz	0.010	0.001	0.001	0.001	0.000	0.000	0.007
Chon-Kyzylsu	0.010	0.002	0.002	0.003	0.000	0.000	0.000
Southern coast							
Dzuuka	0.000	0.002	0.003	0.001	0.000	0.000	0.000
Chon-Dzargylchak	0.000	0.001	0.004	0.001	0.000	0.000	0.000
Barskaun	0.000	0.016	0.003	0.006	0.000	0.000	0.000
Tamga	0.000	0.004	0.003	0.001	0.000	0.000	0.000
Tosor	0.000	0.001	0.002	0.001	0.000	0.000	0.000
Kekliksbulak	0.000	0.002	0.000	0.001	0.000	0.000	0.000
Ton	0.020	0.024	0.000	0.008	0.000	0.000	0.000
Aksai	0.034	0.001	0.000	0.001	0.000	0.000	0.000
Akterek	0.031	0.001	0.001	0.001	0.000	0.000	0.000

Table A-6. Chemical composition (in numerator – g/kg, in denominator – mg-eqv) of the coastal zone water of the Issyk-Kul Lake (1998-2002)

Sampling location		Ca ²⁺	Mg ²⁺	Na ⁺ +K ⁺	HCO ₃ ⁻	CO ₃ ²⁻	SO ₄ ²⁻	Cl ⁻	Mineraliza- tion, mg/dm ³
Western coast	Rybachy	123.4 6.16	282.5 23.23	1475.5 64.15	246.8 4.04	13.0 0.43	2096.2 43.60	1577.3 44.50	5814.7
		105.0 5.24	262.2 21.56	1562.7 67.94	263.5 4.32	28.2 0.94	2137.9 44.51	1595.0 45.00	5954.5
Northern coast	Chyrpykty	107.7 5.38	259.1 21.30	1564.7 68.03	264.7 4.34	28.2 0.94	2140.1 44.56	1591.5 44.89	5956.0
		107.2 5.35	255.4 21.00	1571.7 68.33	268.4 4.40	25.5 0.85	2136.3 44.48	1595.0 45.00	5959.5
	Kursky	105.0 5.24	264.6 21.76	1555.0 67.61	262.3 4.30	28.8 0.96	2131.3 44.37	1595.0 45.00	5942.0
		108.2 5.40	266.0 21.88	1545.8 67.21	259.9 4.26	27.0 0.90	2130.8 44.36	1595.0 45.00	5932.7
	Cholpon-Ata	117.2 5.85	284.6 23.40	1487.9 64.69	238.7 3.91	21.0 0.70	2083.0 43.32	1572.8 44.37	5805.2
		106.2 5.30	278.9 22.94	1497.1 65.09	27.76 4.55	30.0 1.00	2063.9 42.97	1524.1 43.00	5777.8
	Ananievo	108.2 5.40	281.1 23.12	1504.6 65.42	273.5 4.48	26.5 0.88	2034.5 42.32	1541.9 43.50	5770.3
		108.5 5.41	196.4 16.15	525.0 22.83	221.6 3.63	24.0 0.80	995.7 20.73	682.4 19.25	2753.6
	Kurmenty	98.8 4.93	177.2 14.57	446.5 19.41	178.6 2.93	21.9 0.73	940.1 19.57	557.0 15.71	2420.1
		76.2 3.80	178.6 14.69	940.6 40.90	229.5 3.76	22.9 0.76	1351.8 28.14	948.3 26.75	3447.9
	Rogataya bay	104.9 5.23	196.8 16.18	485.5 21.11	190.1 3.12	14.5 0.48	997.9 20.78	638.0 18.00	2627.7
Eastern coast	Tyup	99.38 4.96	187.5 15.42	832.1 36.18	222.0 3.64	21.6 0.72	1540.2 32.07	714.7 20.16	3617.5
		108.2 5.40	191.7 15.76	1348.2 58.62	219.6 3.60	25.0 0.83	1824.6 37.99	1325.8 37.40	5043.1
	Chisty inlet	109.5 5.46	192.5 15.83	1440.1 62.61	231.8 3.80	26.0 0.87	1909.4 39.72	1439.3 40.60	5348.6
		105.5 5.26	190.9 15.70	1248.1 54.27	203.3 3.33	31.0 1.03	1690.4 35.16	1290.4 36.40	4759.6
	Dzergalan	90.73 4.53	172.5 14.19	854.2 37.14	195.7 3.21	21.0 0.70	1397.6 29.10	788.7 22.25	3520.4
		115.2 5.75	184.9 15.21	884.8 38.47	204.4 3.35	22.5 0.75	1458.0 30.36	883.0 24.91	3752.8
	Lipenka bay	81.2 4.05	159.9 13.15	734.4 31.93	143.4 2.35	30.0 1.00	1186.6 24.71	748.0 21.10	3083.5
Southern coast	Pokrovsky	114.0 5.69	269.1 22.13	1381.3 60.06	242.5 3.98	6.0 0.20	2042.6 42.53	1492.4 42.10	5547.9
		103.8 5.18	275.8 22.68	1385.8 60.25	251.3 4.12	18.6 0.62	2062.2 42.94	1430.6 40.36	3728.1
	Tamga	111.0 5.54	223.7 18.40	1442.7 62.73	255.3 4.19	18.0 0.60	2007.4 41.75	1500.3 42.32	5558.4
		162.1 8.09	225.2 18.52	1488.1 64.70	271.5 4.45	16.5 0.55	2050.8 42.70	1547.2 43.65	5761.9
	Koltsovka	142.0 7.09	173.5 14.27	1118.0 48.61	266.5 4.37	15.0 0.50	1361.7 28.35	1311.7 37.00	4388.4
		158.5 7.91	273.3 22.48	1500.7 65.25	268.4 4.40	15.0 0.50	1752.4 36.49	1404.3 39.61	5372.6
	Akterek	109.0 5.44	280.2 23.04	1435.7 62.42	256.2 4.20	6.0 0.20	2056.2 42.81	1521.0 42.89	5664.3

Table A-7. Contents of biogenic elements and organic pollutants (mg/dm³) in the coastal zone water of the Issyk-Kul Lake (1998-2002)

Gulf	N _{NO₂⁻}	N _{NO₃⁻}	N _{NH₄⁺}	P _{total}	Deter- gents	Petroleum	Phenols
Western coast							
Rybachy	0.019	0.157	0.076	0.002	0.006	0.004	0.001
Toruaigyr	0.004	0.122	0.032	0.016	0.003	0.001	0.001
Northern coast							
Chyrpykty	0.003	0.084	0.030	0.014	0.001	0.001	0.001
Chok-Tal	0.002	0.120	0.030	0.012	0.009	0.001	0.001
Kursky	0.000	0.000	0.036	0.016	0.004	0.002	0.001
Dolinka	0.000	0.112	0.020	0.013	0.001	0.002	0.001
Cholpon-Ata	0.006	0.080	0.035	0.005	0.008	0.001	0.001
Grigorievka	0.008	0.005	0.020	0.004	0.009	0.001	0.003
Ananievo	0.016	0.123	0.030	0.000	0.003	0.001	0.001
Kuturga	0.016	0.057	0.013	0.002	0.003	0.001	0.001
Kurmenty	0.014	0.073	0.047	0.001	0.016	0.001	0.001
Shirokaya bay	0.015	0.073	0.020	0.002	0.009	0.001	0.002
Rogataya bay	0.027	0.060	0.020	0.003	0.002	0.001	0.002
Eastern coast							
Tyup	0.006	0.083	0.047	0.014	0.003	0.001	0.001
Shiroky inlet	0.007	0.140	0.000	0.026	0.006	0.001	0.001
Chisty inlet	0.006	0.025	0.005	0.018	0.008	0.000	0.001
Nikolaevsky inlet	0.007	0.000	0.030	0.018	0.002	0.001	0.001
Dzergalan	0.007	0.060	0.025	0.013	0.003	0.001	0.001
Irдыk bay	0.004	0.110	0.080	0.019	0.011	0.001	0.002
Lipenka bay	0.009	0.030	0.050	0.008	0.011	0.001	0.001
Southern coast							
Pokrovsky	0.010	0.060	0.000	0.000	0.000	0.000	0.001
Tamga	0.003	0.100	0.070	0.006	0.001	0.001	0.000
Ak-Chiya	0.000	0.040	0.055	0.015	0.011	0.001	0.009
Kajisay	0.004	0.080	0.085	0.019	0.010	0.001	0.000
Koltsovka	0.017	0.060	0.072	0.017	0.005	0.004	0.008
Ton	0.008	0.080	0.038	0.032	0.007	0.002	0.008
Akterek	0.026	0.040	0.033	0.011	0.009	0.003	0.012

Table A-8. Heavy metal contents (mg/dm³) in the coastal zone water of the Issyk-Kul Lake (1998-2002)

Gulf	Fe	Cu	Zn	Pb	Cd	Sn	As
Western coast							
Rybachy	0.051	0.002	0.004	0.002	0.000	0.020	0.000
Toruaigyr	0.206	0.000	0.000	0.001	0.000	0.001	0.001
Northern coast							
Chyrpykty	0.086	0.001	0.001	0.001	0.000	0.000	0.004
Chok-Tal	0.125	0.001	0.001	0.001	0.000	0.001	0.004
Kursky	0.156	0.007	0.001	0.001	0.000	0.001	0.003
Dolinka	0.184	0.001	0.001	0.001	0.000	0.001	0.003
Cholpon-Ata	0.010	0.001	0.001	0.001	0.000	0.033	0.007
Grigorievka	0.021	0.002	0.000	0.003	0.000	0.007	0.022
Ananievo	0.027	0.000	0.000	0.001	0.000	0.023	0.015
Kuturga	0.033	0.000	0.002	0.001	0.000	0.015	0.013
Kurmenty	0.042	0.000	0.001	0.001	0.000	0.014	0.004
Shirokaya bay	0.025	0.001	0.000	0.001	0.001	0.007	0.010
Rogataya bay	0.028	0.000	0.001	0.001	0.001	0.019	0.007
Eastern coast							
Tyup	0.098	0.011	0.001	0.001	0.000	0.019	0.006
Shiroky inlet	0.000	0.000	0.001	0.001	0.000	0.020	0.006
Chisty inlet	0.090	0.001	0.004	0.001	0.001	0.018	0.007
Nikolaevsky inlet	0.023	0.000	0.007	0.001	0.000	0.019	0.006
Dzergalan	0.079	0.001	0.010	0.001	0.001	0.019	0.005
Irdyk bay	0.000	0.000	0.001	0.001	0.000	0.028	0.010
Lipenka bay	0.040	0.001	0.002	0.001	0.000	0.022	0.004
Southern coast							
Pokrovsky	0.030	0.002	0.005	0.001	0.000	0.000	0.000
Tamga	0.070	0.002	0.001	0.001	0.000	0.038	0.016
Ak-Chiya	0.155	0.001	0.001	0.001	0.000	0.026	0.012
Kajisay	0.000	0.000	0.000	0.001	0.000	0.000	0.000
Koltsovka	0.505	0.001	0.001	0.001	0.000	0.007	0.016
Ton	0.117	0.001	0.001	0.001	0.000	0.023	0.008
Akterek	0.141	0.001	0.001	0.001	0.000	0.042	0.004

**Table A-9. Silica and fluorine contents
(mg/dm³) in gulf waters of the Issyk-
Kul Lake (1998-2002)**

Gulf	Depth, m	Si	F
Rybachy	0.5	1.9	12.8
	10	1.9	14.3
	20	1.9	14.3
Cholpon- Ata	0.5	2.0	12.6
	10	1.9	13.2
	30	2.0	14.0
	50	1.9	14.0
Tyup	0.5	2.2	8.9
	10	1.8	12.7
	20	1.8	12.8
	30	2.0	13.3
	40	1.8	13.2
Dzergalan	0.5	1.9	5.7
	10	1.9	13.5
	20	1.9	13.2
	30	1.9	13.5
	100	1.9	13.5
Pokrovsky	0.5	1.9	11.7
	40	1.9	14.0
Kajisay	0.5	1.8	12.3
	10	1.8	13.5
	40	1.8	13.5
	100	1.9	13.0
Ton	0.5	2.0	11.5
	10	1.8	14.0
	40	1.9	14.0

Table A-10. Chemical composition of the deep waters of the Issyk-Kul Lake, 2002

Depth, m	Ca ²⁺	Mg ²⁺	Na ⁺ +K ⁺	HCO ₃ ⁻	CO ₃ ⁻	SO ₄ ²⁻	Cl ⁻	Mineraliza- tion, mg/dm ³
	Concentration (in numerator – g/kg, in denominator – mg-eqv)							
0.5	111.9	279.7	1517.3	269.4	22.7	2122.8	1601.3	5925.1
	5.58	23.00	65.97	4.42	0.76	44.20	45.17	
10.0	113.5	281.7	1520.1	271.5	22.0	2140.9	1601.3	5951.0
	5.66	23.17	66.09	4.45	0.73	44.57	45.17	
20.0	111.9	283.7	1527.2	266.4	22.5	2138.4	1618.9	5969.0
	5.58	23.33	66.40	4.37	0.75	44.52	45.67	
30.0	118.5	279.7	1534.1	268.4	24.5	2164.2	1607.1	5996.5
	5.91	23.00	66.70	4.40	0.82	45.06	45.33	
40.0	111.9	279.7	1536.2	266.4	23.5	2151.6	1610.0	5979.3
	5.58	23.00	66.79	4.37	0.78	44.80	45.42	
50.0	110.2	285.8	1527.4	268.4	21.0	2148.3	1615.9	5977.0
	5.50	23.50	66.41	4.40	0.70	44.73	45.58	
100.0	116.9	282.7	1550.7	268.9	21.5	2164.8	1618.9	6024.4
	5.83	23.25	67.42	4.41	0.72	45.07	45.67	
200.0	116.9	281.7	1531.8	263.9	23.5	2148.9	1621.8	5988.5
	5.83	23.17	66.60	4.33	0.78	44.74	45.75	
300.0	118.5	281.7	1535.3	266.9	22.0	2153.5	1626.3	6004.2
	5.91	23.17	66.75	4.38	0.73	44.84	45.88	
400.0	120.2	281.2	1533.6	270.0	24.0	2159.3	1617.4	6005.7
	6.00	23.13	66.68	4.43	0.80	44.96	45.62	
500.0	115.2	285.8	1540.5	268.4	27.0	2184.2	1613.0	6034.1
	5.75	23.50	66.98	4.40	0.90	45.43	45.50	
650.0	118.3	282.5	1549.7	266.4	24.5	2190.0	1620.6	6052.0
	5.90	23.23	67.38	4.37	0.82	45.60	45.72	

Table A-11. Contents of biogenic elements and organic pollutants (mg/dm³) in the deep waters of the Issyk-Kul Lake 2002

Depth, m	N _{NO₂⁻}	N _{NO₃⁻}	N _{NH₄⁺}	P _{total}	Petroleum
0.5	0.003	0.050	0.020	0.005	0.001
10.0	0.003	0.000	0.013	0.004	0.000
20.0	0.004	0.070	0.017	0.009	0.000
30.0	0.003	0.040	0.017	0.004	0.000
40.0	0.004	0.037	0.023	0.002	0.000
50.0	0.006	0.087	0.010	0.006	0.000
100.0	0.005	0.073	0.017	0.002	0.000
200.0	0.004	0.090	0.020	0.003	0.000
300.0	0.002	0.103	0.037	0.002	0.000
400.0	0.003	0.080	0.035	0.002	0.000
500.0	0.004	0.050	0.030	0.001	0.000
650.0	0.004	0.050	0.023	0.001	0.000

Table A-12. Heavy metal contents (mg/dm³) in deep waters of the Issyk-Kul Lake (2001-2002)

Depth, m	Fe	Cu	Zn	Pb	Cd	Sn	As
0.5	0.011	0.001	0.001	0.001	0.000	0.002	0.003
10.0	0.020	0.001	0.001	0.001	0.000	0.002	0.003
20.0	0.013	0.001	0.000	0.001	0.000	0.001	0.002
30.0	0.029	0.001	0.000	0.001	0.000	0.001	0.001
40.0	0.021	0.001	0.000	0.001	0.000	0.002	0.002
50.0	0.030	0.001	0.000	0.001	0.000	0.002	0.002
100.0	0.033	0.001	0.000	0.000	0.000	0.001	0.002
200.0	0.036	0.000	0.000	0.001	0.000	0.001	0.002
300.0	0.021	0.001	0.000	0.001	0.000	0.002	0.002
400.0	0.012	0.001	0.000	0.001	0.000	0.001	0.001
500.0	0.000	0.001	0.000	0.001	0.000	0.000	0.002
650.0	0.001	0.001	0.000	0.001	0.000	0.000	0.001

Table A-13. Granulometric composition of various sediment fractions (wt %) of the Issyk-Kul Lake coastal zone, (2000-2002)

Sampling location		Diameter of particles, mm			
		1-0.25 sand	0.25-0.01 dust	0.01-0.001 silt	<0.001 clay
Western coast	Rybachy	18.1	61.4	15.0	5.5
	Toruaigyr	7.2	68.1	22.5	2.2
Northern coast	Chyrpykty	20.7	59.3	16.4	3.6
	Chok-Tal	15.4	64.7	15.5	4.4
	Kursky	4.8	85.3	7.4	2.5
	Dolinka	8.6	82.1	7.3	2.0
	Cholpon-Ata	6.9	70.7	17.3	5.1
	Grigorievka	15.8	57.7	22.8	3.7
	Ananievo	31.8	51.0	15.5	1.7
	Kuturga	5.4	64.2	23.8	6.6
	Kurmenty	0.5	42.4	44.9	12.2
	Shirokaya bay	1.7	46.9	39.5	11.9
	Rogataya bay	0.9	54.9	35.6	8.6
Eastern coast	Tyup	27.9	28.8	30.5	12.8
	Shiroky inlet	0.3	53.6	34.5	11.6
	Chisty inlet	1.8	52.9	36.2	9.1
	Nikolaevsky inlet	0.5	62.4	28.5	8.6
	Dzergalan	0.9	66.0	29.4	3.7
	Irdyk bay	46.2	46.1	7.0	0.7
	Lipenka bay	3.5	82.2	13.4	0.9
Southern coast	Pokrovsky	5.2	69.2	22.8	2.8
	Barskaun	1.0	85.0	12.1	1.9
	Tamga	25.0	66.8	6.0	2.2
	Ak-Chiya	11.6	66.6	17.5	4.3
	Kajisay	45.9	44.7	7.6	1.8
	Koltsovka	36.8	53.8	7.4	2.0
	Ton	3.4	58.0	33.3	5.3
	Akterek	4.7	76.0	16.1	3.2

Table A-14. Chemical composition of sediment (in numerator – g/kg, in denominator – mg-eqv/kg) of the Issyk-Kul Lake coastal zone (2000-2002)

Gulf		Ca ²⁺	Mg ²⁺	Na ⁺ +K ⁺	HCO ₃ ⁻	CO ₃ ²⁻	SO ₄ ²⁻	Cl ⁻	Mineraliza- tion, mg/kg
Western coast	Rybachy	0.22	1.31	3.50	0.85	0.04	5.22	5.32	16.46
		1.10	10.88	15.20	1.40	0.12	10.88	15.76	
	Toruaigyr	0.66	0.79	1.95	0.62	0.07	5.46	2.01	11.56
		3.30	6.58	8.49	1.02	0.23	11.38	5.74	
Northern coast	Chyrpykty	0.59	0.73	1.87	0.56	0.08	5.19	1.81	10.83
		2.94	6.08	8.15	0.92	0.27	10.81	5.17	
	Chok-Tal	0.78	0.78	2.24	0.59	0.06	5.72	2.47	12.64
		3.90	6.50	9.75	0.97	0.20	11.92	7.06	
	Kursky	0.45	0.95	2.19	0.71	0.08	5.14	2.64	12.16
		2.25	7.92	9.50	1.16	0.27	10.70	7.54	
	Dolinka	0.79	0.72	2.12	0.67	0.07	5.74	2.05	12.16
		3.95	6.00	9.20	1.10	0.23	11.96	5.86	
	Cholpon-Ata	0.89	1.20	3.36	1.47	0.07	4.99	5.73	17.71
		4.43	10.02	14.61	2.42	0.21	10.40	16.02	
	Grigorievka	0.78	0.53	2.62	0.87	0.03	5.01	2.60	12.44
		3.90	4.43	11.38	1.43	0.10	10.76	7.43	
	Ananievo	0.89	0.66	3.50	0.75	0.04	7.71	2.71	16.25
		4.43	5.50	15.20	1.23	0.12	16.05	7.73	
	Kuturga	0.56	0.45	2.68	0.85	0.06	4.53	2.49	11.62
		2.80	3.70	11.64	1.40	0.20	9.44	7.10	
	Kurmenty	0.50	0.66	3.48	1.16	0.04	5.91	3.04	14.79
		2.50	5.50	15.12	1.90	0.12	12.31	8.80	
Eastern coast	Tyup	0.61	0.49	2.78	0.81	-	4.69	2.84	12.22
		3.04	4.08	12.13	1.33	-	9.77	8.12	
	Shiroky inlet	0.64	0.74	3.69	0.89	-	6.01	3.99	15.96
		3.20	6.13	16.06	1.47	-	12.53	11.40	
	Chisty inlet	0.59	0.55	3.69	0.81	-	5.59	3.69	14.92
		2.93	4.53	16.06	1.33	-	11.64	10.53	
	Nikolaevsky inlet	0.81	0.80	3.72	0.85	-	6.77	3.99	16.94
		4.07	6.67	16.17	1.40	-	14.10	11.40	
	Dzergalan	0.62	0.45	1.90	0.94	-	3.85	1.93	9.69
		3.10	3.70	8.25	1.53	-	8.02	5.50	
Southern coast	Irdyk bay	0.42	0.34	0.28	0.43	-	1.64	0.40	3.81
		2.10	2.78	1.23	0.70	-	3.43	2.00	
	Lipenka bay	0.78	0.51	1.09	0.61	-	3.91	1.30	8.20
		3.90	4.20	4.74	1.00	-	8.14	3.70	
	Pokrovsky	0.31	0.47	0.20	1.01	-	1.58	0.61	4.18
		1.55	3.88	1.01	1.65	-	3.29	1.75	
	Barskaun	0.33	0.31	0.89	0.81	-	2.69	0.42	5.45
		1.67	2.60	3.87	1.33	-	5.60	1.20	
	Tamga	0.72	0.62	2.14	1.46	0.09	3.28	3.04	11.35
		3.60	5.20	9.29	1.73	0.30	6.82	8.80	
	Ak-Chiya	0.75	0.81	1.19	1.42	-	2.77	2.63	9.57
		3.73	6.69	5.18	3.00	-	5.77	7.50	
	Kajisay	0.31	0.23	0.98	0.71	-	2.51	0.44	5.18
		1.55	1.87	4.25	1.17	-	5.22	1.27	
	Koltsovka	0.67	0.61	0.93	1.04	0.06	2.14	2.13	7.58
		3.33	5.07	4.04	1.70	0.20	4.45	6.08	
	Ton	0.66	0.56	1.05	1.33	0.08	2.20	2.09	7.97
		3.31	4.85	4.70	2.18	0.24	4.58	5.96	
	Akterek	0.66	0.54	1.69	1.17	0.06	2.14	2.13	7.58
		3.31	4.46	7.85	1.92	0.20	4.45	6.08	

Table A-15. Heavy metal contents (mg/kg) in sediment of the Issyk-Kul Lake coastal zone (2000-2002)

Gulf	Cu	Zn	Pb	Cd	Sn
Western coast					
Rybachy	7.64	1.35	8.67	0.00	2.81
Toruaigyr	6.690	9.254	3.584	0.005	0.532
Northern coast					
Chyrpykty	5.144	5.774	5.016	0.005	0.932
Chok-Tal	2.892	7.040	4.678	0.000	0.802
Kursky	5.896	8.104	2.452	0.076	0.610
Dolinka	5.334	4.906	5.064	0.058	0.558
Cholpon-Ata	5.23	2.80	9.68	0.00	1.84
Grigorievka	4.60	1.84	7.73	0.00	1.04
Ananievo	7.50	1.57	4.58	0.00	1.00
Kuturga	5.39	2.09	4.27	0.00	1.08
Kurmenty	4.37	8.04	4.16	0.00	0.95
Shirokaya bay	1.51	4.14	7.20	0.00	1.12
Rogataya bay	5.90	0.00	5.19	0.00	1.14
Eastern coast					
Tyup	8.06	0.00	11.98	0.00	1.06
Shiroky inlet	10.27	0.00	21.20	0.00	0.95
Chisty inlet	15.15	Trace	17.93	0.00	0.67
Nikolaevsky inlet	13.63	0.00	17.20	0.00	0.75
Dzergalan	17.92	0.00	18.82	0.00	1.08
Irdyk bay	7.86	0.00	12.60	0.00	0.67
Lipenka bay	14.09	0.00	17.65	0.00	0.70
Southern coast					
Pokrovsky	0.00	3.68	8.83	0.00	3.86
Barskaun	0.00	5.57	7.67	0.31	2.51
Tamga	3.18	7.68	11.46	0.00	0.63
Ak-Chiya	12.46	31.71	17.47	0.05	0.87
Kajisay	0.00	0.00	4.77	0.07	2.81
Koltsovka	9.79	16.98	22.24	0.00	1.28
Ton	8.43	2.05	10.69	0.00	1.60
Akterek	9.09	12.84	11.26	0.00	0.74

Table A-16. Granulometric content (%) of sediment the Issyk-Kul lake deep zone, 2001-2002

Sampling location	Interval, cm	1-0.25	0.25-0.05	0.05-0.01	0.01-0.005	0.005-0.001	<0.001	Sand	Dust	Silt	Clay
Cores											
Cholpon-Ata gulf, depth of 70 m	0-5	0.6	25.8	38.3	12.2	20.0	3.1	0.6	64.1	32.2	3.1
	5-10	0.5	19.4	36.2	15.5	24.1	4.3	0.5	55.6	39.6	4.3
	10-20	0.4	25.0	26.4	24.3	20.8	3.1	0.4	51.4	45.1	3.1
	20-30	0.3	19.5	36.4	16.6	22.7	4.5	0.3	55.9	39.3	4.5
	30-40	0.4	19.3	38.1	17.4	19.5	5.3	0.4	57.4	36.9	5.3
	40-50	0.2	20.0	36.4	17.5	23.1	2.8	0.2	56.4	40.6	2.8
Kajisay gulf, depth of 110 m	50-55	0.4	21.6	32.0	15.3	27.3	3.4	0.4	53.6	42.6	3.4
	0-5	2.0	24.4	36.5	15.7	16.9	4.5	2.0	60.9	32.6	4.5
	5-10	0.7	15.8	48.5	12.4	18.2	4.4	0.7	64.3	30.6	4.4
	10-20	0.3	10.7	51.8	15.8	16.5	4.9	0.3	62.5	32.3	4.9
	20-30	1.9	11.9	54.1	14.8	14.2	3.1	1.9	66.0	29.0	3.1
	30-35	2.6	14.4	47.2	11.1	19.0	5.7	2.6	61.6	30.1	5.7
Tosor gulf, depth of 125 m	0-5	0.4	34.1	43.1	10.5	8.5	3.4	0.4	77.2	19.0	3.4
	5-10	2.6	52.3	26.7	7.5	9.0	1.9	2.6	79.0	16.5	1.9
	10-20	1.4	24.4	44.5	11.4	14.6	3.7	1.4	68.9	26.0	3.7
Barskaun gulf, depth of 185 m	0-5	0.5	23.0	33.1	12.4	28.6	2.4	0.5	56.1	41.0	2.4
	5-10	0.6	25.6	31.0	5.9	33.7	3.2	0.6	56.6	39.6	3.2
	10-20	0.6	21.5	27.5	13.3	33.5	3.6	0.6	49.0	46.8	3.6
	20-30	1.4	18.9	34.0	12.6	27.9	5.2	1.4	52.9	40.5	5.2
	30-40	2.0	32.7	34.1	12.2	16.6	2.4	2.0	66.8	28.8	2.4
	40-45	2.8	30.1	46.5	10.8	7.9	2.8	2.8	76.6	18.7	2.8
Deep zone											
Station 1	300	0.5	17.4	42.9	10.1	29.1	4.2	0.5	60.3	39.2	4.2
Station 2	400	0.4	17.8	41.6	9.1	27.0	4.1	0.4	59.4	36.1	4.1
Station 3	510	0.5	12.6	37.4	11.0	35.8	2.7	0.5	50.0	46.8	2.7

Table A-17. Chemical composition of the Issyk-Kul Lake deep zone sediment (2001-2002)

Sampling location	Interval, cm	Concentration (in numerator – g/kg, in denominator – mg-equiv)							Mineralization, mg/kg	pH
		Ca ²⁺	Mg ²⁺	Na ⁺ +K ⁺	HCO ₃ ⁻	CO ₃ ²⁻	SO ₄ ²⁻	Cl ⁻		
Cores										
Barskaun, depth of 185 m	0-5	0.36	0.36	2.12	1.34	-	3.28	1.75	9.21	7.35
		1.80	3.00	9.21	2.20		6.81	5.00		
	5-10	0.36	0.34	2.07	1.34	-	3.18	1.75	9.04	7.35
		1.80	2.80	9.01	2.20		6.61	5.00		
	10-15	0.40	0.36	1.84	1.34	0.06	2.81	1.66	8.47	7.34
		2.00	3.00	7.99	2.20	0.20	5.84	4.75		
	15-20	0.40	0.36	1.91	1.46	0.06	2.86	1.66	8.71	7.34
		2.00	3.00	8.30	2.40	0.20	5.95	4.75		
	20-25	0.40	0.34	1.80	1.46	0.06	2.77	1.49	8.32	7.33
		2.00	2.80	7.82	2.40	0.20	5.77	4.25		
	25-30	0.36	0.34	1.85	1.46	-	2.87	1.49	8.37	7.30
		1.80	2.80	8.03	2.40		5.98	4.25		
	30-35	0.36	0.31	1.81	1.34	0.09	2.78	1.40	8.09	7.33
		1.80	2.60	7.89	2.20	0.30	5.79	4.00		
	35-40	0.32	0.31	1.39	1.34	0.09	1.93	1.31	6.69	7.35
		1.60	2.60	6.06	2.20	0.30	4.01	3.75		
40-45	0.32	0.29	1.36	1.34	0.09	1.88	1.23	6.51	7.35	
	1.60	2.40	5.92	2.20	0.30	3.92	3.50			
Beam of the Tosor river, depth of 125 m	0-5	0.36	0.36	2.90	1.22	-	4.60	2.03	11.47	7.18
		1.80	3.00	12.59	2.00		9.59	5.80		
	5-10	0.32	0.26	2.91	1.10	-	4.44	1.89	10.92	7.21
		1.60	2.20	12.64	1.80		9.24	5.40		
	10-15	0.32	0.26	2.48	1.10	-	3.53	1.89	9.58	7.21
		1.60	2.20	10.76	1.80		7.36	5.40		
	15-20	0.28	0.26	2.48	1.10	-	3.36	1.96	9.44	7.19
		1.40	2.20	10.80	1.80		7.00	5.60		
Deep zone										
Station 1	300	0.46	0.72	0.70	0.67	0.06	2.92	1.39	6.92	7.97
		2.30	6.00	3.04	1.10	0.20	6.08	3.96		
Station 2	400	0.6	0.71	0.69	0.67	0.06	2.87	1.38	6.84	7.92
		2.30	5.90	3.02	1.10	0.20	5.98	3.94		
Station 3	510	0.44	0.74	0.75	0.73	0.06	3.01	1.40	7.13	7.96
		2.20	6.20	3.27	1.20	0.20	6.27	4.00		

Table A-18. Heavy metal contents (mg/kg) in the Issyk-Kul Lake deep zone sediment cores (2001-2002)

Sampling location	Interval, cm	Cu	Zn	Pb	Sn
Cores					
Cholpon-Ata, depth of 70 m	0-5	6.60	0.23	9.40	0.00
	6-10	5.50	0.41	8.70	0.00
	11-15	5.81	0.40	9.10	0.00
	16-20	5.60	0.47	9.53	0.00
	21-25	5.70	0.69	9.33	0.00
	26-30	4.32	0.65	7.40	0.00
	31-35	4.40	0.98	9.20	0.00
	36-40	3.30	0.69	6.94	0.00
	41-45	3.61	0.80	6.40	0.00
	46-50	3.20	0.43	4.42	0.00
	51-55	2.20	0.00	4.60	0.00
Kajisay, depth of 110 m	0-5	5.93	0.00	10.50	1.17
	6-10	5.71	0.00	11.70	0.94
	11-15	6.25	0.00	9.34	0.75
	16-20	6.40	0.00	14.50	0.72
	21-25	6.90	0.00	16.50	0.51
	26-30	7.40	0.00	16.90	Trace
	31-35	5.70	0.00	10.80	trace
Beam of the Tosor river, depth of 125 m	0-5	0.37	0.32	7.64	3.30
	6-10	0.32	0.11	7.21	2.92
	11-15	0.27	0.24	6.62	3.24
	16-20	0.29	0.37	6.40	2.76
Barskaun, depth of 185m	0-5	1.40	0.06	4.40	0.00
	6-10	1.30	0.11	4.70	0.00
	11-15	0.90	0.16	3.74	0.00
	16-20	0.63	0.93	7.90	0.00
	21-25	0.55	0.98	5.10	0.00
	26-30	0.44	1.62	5.40	0.00
	31-35	0.32	1.21	5.80	0.00
	36-40	0.21	1.11	6.23	0.00
	41-45	0.25	1.01	5.70	0.00
Deep zone					
Station 1	300	1.53	2.02	4.06	0.76
Station 2	400	2.22	1.71	3.78	0.94
Station 3	510	1.77	2.31	4.69	0.82

Note: cadmium was not found in all studied samples.

Table A-19. Average chemical composition of natural waters and sediment of the Issyk-Kul Lake (1998-2002)

Ions	Rivers		Water				Sediment			
			Coastal zone		Deep zone		Coastal zone		Deep zone	
	mg/dm ³	mg-equiv	g/kg	mg-equiv	g/kg	mg-equiv	g/kg	mg-equiv	g/kg	mg-equiv
Ca ²⁺	50.5	2.52	0.111	5.54	0.115	5.72	0.610	3.05	0.450	2.25
Mg ²⁺	8.5	0.70	0.230	18.89	0.281	23.08	0.630	5.25	0.720	6.00
Na ⁺ +K ⁺	11.7	0.51	1.221	53.07	1.525	66.29	2.339	10.17	0.727	3.16
CO ₃ ²⁻	1.5	0.05	0.022	0.72	0.023	0.77	0.081	0.27	0.060	0.20
HCO ₃ ⁻	137.3	2.25	0.238	3.90	0.267	4.37	0.903	1.48	0.702	1.15
SO ₄ ²⁻	54.8	1.14	1.768	36.81	2.144	44.65	4.488	9.35	2.928	6.10
Cl ⁻	10.3	0.29	1.279	36.07	1.606	45.30	2.580	7.37	1.386	3.96
Mineralization	274.6		4.869		5.961		11.631		6.973	

Table A-20. Anthropogenic component of river drain of the Issyk-Kul hollow

Ions	Back-ground content, mg/l	Composition of river water, mg/l	Water drain, m ³ /s	Ion back-ground drain, ton·10 ³	Ion river drain, ton·10 ³	Anthropogenic component, ton·10 ³	Anthropogenic component, %
Ca ²⁺	26.3	26.6	49.53	41.08	41.55	0.47	1.1
Mg ²⁺	4.7	7.7	49.53	7.34	12.03	4.69	63.9
Na ⁺ +K ⁺	3.7	19.0	49.53	5.78	29.68	23.90	413.5
HCO ₃ ⁻	91.5	91.9	49.53	142.92	143.55	0.63	0.4
SO ₄ ²⁻	22.4	51.2	49.53	34.99	79.97	44.98	128.6
Cl ⁻	6.0	9.5	49.53	9.37	14.84	5.47	58.4
Ion sum	154.6	205.9	49.53	241.48	321.62	80.14	33.2

Anthropogenic component of pollutant river drain of the Issyk-Kul hollow

Pollut-ants	Back-ground content, mg/l	Content in river water, mg/l	Water drain, m ³ /s	Back-ground drain, ton·10 ³	Pollut-ants drain, ton·10 ³	Anthropogenic component, ton·10 ³	Anthropogenic component, %
BOC ₅	1.35	2.32	49.53	2.11	3.62	1.51	71.6
COC	8.61	15.48	49.53	13.45	24.18	10.73	79.8
Copper	0.002	0.002	49.53	0.003	0.003	0.00	0.00
Zinc	0.002	0.002	49.53	0.003	0.003	0.00	0.00
Deter-gents	0.001	0.011	49.53	0.001	0.017	0.016	76.0
Phenols	0.00	0.002	49.53	0.00	0.003	0.003	100.0
Petro-leum	0.001	0.050	49.53	0.001	0.078	0.077	77.0
Pesti-cides	0.00	0.001	49.53	0.00	0.001	0.001	100.0
Pollut-ant sum	9.964	17.866	49.53	15.566	27.904	12.339	79.3

Table A-21. Anthropogenic component in natural waters of the Issyk-Kul hollow

Name of natural water	BOC ₅	COC	Cu	Zn	Detergents	Phenols	Petroleum	Chemical pestkillers	Anthropogenic component
Background content	1.35	8.61	0.002	0.002	0.001	0.001	0.01	0.000	
Atmospheric precipitation	-	0.15	0.001	trace	0.00	0.00	0.00	0.000	-
Rivers	2.32 1.72	15.48 1.80	0.004 2	0.002 -	0.012 12	0.001 -	0.35 35	0.001	52.52
Springs	2.43 1.80	11.74 1.36	0.003 1.5	0.002 -	0.003 3	Trace -	0.05 5		12.66
Artesian wells	-	8.62	0.002	0.002	0.003 3	0.001 -	0.02 2	0.000	5.0
Ground waters	4.89 3.62	15.18 1.76	0.003 1.5	0.005 2.5	0.003 3	0.001 -	0.35 35	0.002	47.38
Coastal zone of the lake	2.28 1.68	-	0.003 1.5	0.003 1.5	0.012 12	0.002 2	0.39 39	0.001	57.68
Deep zone of the lake	1.04 -	-	0.002 -	0.006 3	0.000 -	0.001 -	0.01 -	-	3.0
Domestic sewage	54.2 40.15	2.48 28.8	0.004 2	0.006 3	0.25 250	0.004 4	0.70 70	0.000	397.95
Industrial drains	32.0 23.70	113.9 13.23	0.006 3	0.008 4	0.05 50	0.002 2	0.08 8	0.000	103.93

Note: in numerator – pollutant content (mg/dm³),
in denominator – exceeding background content in some times.

Table A-22. Condition of natural water pollution of the Issyk-Kul hollow

Name of natural water	BOC ₅	COC	Cu	Zn	Detergents	Phenols	Petroleum	Chemical pestkillers	Total pollution index
MPC norms	3.0	30.0	0.001	0.01	0.5	0.001	0.05	Absence	
Rivers	2.32	15.48	0.004	0.002	0.012	0.001	0.35	0.001	14.0
	-	-	4	2	-	-	7	1	
Springs	2.43	11.74	0.003	0.002	0.003	0.000	0.05	0.000	5.0
	-	-	3	2	-	-	-	-	
Artesian wells	-	8.62	0.002	0.002	0.003	0.001	0.02	0.000	4.0
	-	-	2	2	-	-	-	-	
Ground waters	4.89	15.18	0.003	0.005	0.003	0.001	0.35	0.002	18.63
	1.63	-	3	5	-	-	7	2	
Coastal zone of the lake	2.28	-	0.003	0.003	0.012	0.002	0.39	0.001	16.8
	-	-	3	3	-	2	7.8	1	
Deep zone of the lake	1.04	-	0.002	0.006	0.000	0.001	0.01	-	8.0
	-	-	2	6	-	-	-	-	
Domestic sewage	54.2	248.0	0.004	0.006	0.25	0.004	0.70	0.000	54.34
	18.07	8.27	4	6	-	4	14	-	
Industrial drains	32.0	113.9	0.006	0.008	0.05	0.002	0.08	0.000	23.07
	10.67	3.80	6	8	-	2	1.6	-	

Note: in numerator – pollutant content (mg/dm³),
in denominator – exceeding MPC in some times.

Table A-23. Diffusion of heavy metals in the Issyk-Kul hollow

Object name	Fe	Cu	Zn	Pb	Cd	Sn	As
Precipitation rocks, mg/kg	48.0	45.0	8.3	0.03	0.003	0.003	0.000
River suspended substances, mg/kg	9.5	2.66	4.0	5.6	0.000	0.300	0.000
River water, mg/dm ³	0.013	0.007	0.002	0.002	0.001	0.000	0.001
Coastal zone water of the lake, mg/dm ³	0.084	0.003	0.002	0.002	0.001	0.028	0.016
Deep zone water of the lake, mg/dm ³	0.011	0.001	0.007	0.002	0.001	0.022	0.009
Coastal zone sediment of the lake, mg/kg	-	8.60	11.50	12.45	0.140	0.94	0.000
Deep zone sediment of the lake, Depth of 100.0-200.0 m, mg/kg	-	2.76	5.50	8.26	0.000	1.94	-
Depth of 300.0-510.0 m, mg/kg	-	1.84	2.01	6.27	0.000	0.84	-

Table A-24. Relative content of heavy metals in the Issyk-Kul lake sediment (c_i/c_b) and pollution index (PI)

Gulf	Cu	Zn	Pb	Cd	Sn	$PI = \sum (c_i/c_b)$
Coastal zone						
Rybachy	2.87	0.34	1.55	0.00	9.37	14.13
Toruaigyr	2.52	2.31	0.64	0.01	1.77	7.25
Chyrpykty	1.93	1.44	0.90	0.01	3.11	7.39
Chok-Tal	1.09	1.76	0.84	0.00	2.67	6.36
Kursky	2.22	2.03	0.44	0.08	2.03	6.80
Dolinka	2.01	1.23	0.90	0.06	1.86	6.06
Cholpon-Ata	1.97	0.70	1.73	0.00	6.13	10.53
Grigorievka	1.73	0.46	1.38	0.00	3.47	7.04
Ananievo	2.82	0.39	0.82	0.00	3.33	7.36
Kuturga	2.03	0.52	0.76	0.00	3.60	6.91
Kurmenty	1.64	2.01	0.74	0.00	3.17	7.56
Shirokaya bay	0.57	1.04	1.29	0.00	3.73	6.63
Rogataya bay	2.22	0.00	0.93	0.00	3.80	6.95
Tyup	3.03	0.00	2.14	0.00	3.53	8.70
Shiroky inlet	3.86	0.00	3.79	0.00	3.17	10.82
Chisty inlet	5.70	0.00	3.20	0.00	2.23	11.13
Nikolaevsky inlet	5.12	0.00	3.07	0.00	2.50	10.69
Dzergalan	6.74	0.00	3.36	0.00	3.60	13.70
Irдыk bay	2.95	0.00	2.25	0.00	2.23	7.43
Lipenka bay	5.30	0.00	3.15	0.00	2.33	10.78
Pokrovsky	0.00	0.92	1.58	0.00	3.23	5.73
Barskaun	0.00	1.39	1.37	0.31	8.37	11.44
Tamga	1.20	1.92	2.05	0.00	2.10	7.27
Ak-Chiya	4.68	7.93	3.12	0.05	2.90	18.68
Kajisay	0.00	0.00	0.85	0.07	9.37	10.29
Koltsovka	3.68	4.25	3.97	0.00	4.27	16.17
Ton	3.17	0.51	1.91	0.00	5.33	10.92
Akterek	3.42	3.21	2.01	0.00	2.47	11.11
Deep zone						
Cholpon-Ata	1.72	0.15	1.38	0.00	0.00	3.25
Barskaun	0.25	0.20	0.97	0.00	0.00	1.42
Kajisay	2.38	0.00	3.22	0.00	2.73	8.33
Tosor	0.12	0.07	1.24	0.00	10.20	11.63
Open part of the lake, Depth of 300-510 m	0.69	0.50	0.75	0.00	2.80	4.74